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MR. JAMES W. DAVIS, F.G.S., F.L.S., F.S.A.

THE

TRANSACTIONS

OF THE

LEEDS

Geological Association.

PART VIII.

1892-3.

EDITED BY
W. LOWER CARTER, M.A., F.G.S.,
Honorary Secretary.

Leeds:
PRINTED AND PUBLISHED BY RICHARD CROSLAND, 69, WOODHOUSE LANE,
1893.

NOTE.

The Authors alone are responsible for the facts and opinions contained in their respective papers.

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FRONTISPIECE—Portrait of the late Mr. James W. Davies, F.G.S., F.L.S., F.S.A., of Halifax.

REPORT OF THE COUNCIL.

June 15th, 1893.

IN presenting to the Members their NINETEENTH ANNUAL REPORT, the Council of the Leeds Geological Association feel much pleasure in being able to record a year of steady progress in the work of the Association, and one in which they have made special efforts to put the Society on a sound financial basis, and to promote its scientific usefulness.

MEMBERSHIP.

The Roll of Membership which has been carefully revised during the year, now contains the names of 10 Honorary and 108 Ordinary Members. Sixteen new Members have joined the Association since last June.

MEETINGS.

During the past Session there have been, as usual, nine evening meetings of the Association, all the papers read being contributed by the Members. The Presidential Address brought forward many interesting points about Coral Islands, and their mode of formation. Mr. Hardcastle's careful abstract of what is known about Chalk and Flint, and the results of Mr. Holgate's long observation of the Action of Water on the Rocks of Yorkshire, were welcome additions to our programme; and Dr. Forsyth contributed the second of his papers on Scottish Geology. Theoretical Geology was well represented by Mr. Kendall's interesting argument as to the Cause of the Ice Age, and Professor Miall's valuable contribution to the elucidation of the History of the Globe, from the study of the distribution of plants and animals. Mr. Tate's promised demonstration of Rock Sections was postponed owing to the difficulty of obtaining a suitable apparatus for the public exhibition of polarized sections, but it is hoped that the exhibition will be forthcoming early next session. Two evenings were taken up by Holiday Notes, which produced several interesting and important papers.

1. Opening Meeting and Social Evening. Address by the President, Mr. John Ingleby, on "Coral Islands." Exhibition of new lantern slides.
2. Paper on "Chalk and Flint," by Mr. C. D. Hardcastle.

3. Holiday Notes. Paper by Mr. S. W. Cuttriss, on "The Parallel Roads of Glen Roy." Account of "A Tour round the World," by Mr. John Redmayne.

4. Paper by Mr. David Forsyth, M.A., D.Sc., on "The General Geology of Scotland."

5. Holiday Notes (continued). Paper by Mr. A. Farrar, F.G.S., on "The Coast between Eastbourne and Folkstone." Paper by Mr. William Cheetham, F.G.S., entitled "Round Scotland in Five Days." Paper by Mr. E. Hawkesworth, on "Notes on some Withernsea Specimens."

6. Paper by Mr. Percy F. Kendall, F.G.S., on "The Cause of the Ice Age."

7. Paper by Mr. Benjamin Holgate, F.G.S., on "Some Examples of Change in Rock, caused by the permeation of Underground Water."

8. Lecture by Professor L. C. Miall, F.R.S., F.G.S., on "The Distribution of Plants and Animals as affected by the past history of the Earth."

9. Annual Meeting. Election of Officers, and General Business. Exhibition of Specimens.

EXCURSIONS.

Several interesting and instructive excursions have been taken during the year, including those arranged by the Yorkshire Naturalists' Union. The Council tender their hearty thanks to the gentlemen who have conducted these excursions, and whose efforts have so largely insured their success.

1. Dunford Bridge. (Y.N.U.) Upper Carboniferous. Leader, Mr. Joseph Field.
2. Meanwood Valley. Upper Carboniferous. Leader, Mr. W. L. Carter, M.A., F.G.S.
3. Draughton and Hambledon. Carboniferous Limestone. Leader, Mr. W. L. Carter, M.A., F.G.S.
4. Brimham Rocks. Millstone Grit. Leader, Mr. Chas. Brownridge, F.G.S.
5. Withernsea. (Y.N.U.) Pleistocene. Leader, Mr. Alfred Harker, M.A., F.G.S.
6. Reevah. Millstone Grit and Glacial Drift. Leader, Mr. William Cheetham, F.G.S.
7. Coxwold and Byland. (Y.N.U.) Oolites. Leaders, Mr. S. Chadwick, F.G.S., and Rev. T. A. Burge.
8. Otley Chevin. Millstone Grit. Leader, Mr. William Cheetham, F.G.S.
9. Aysgarth. (Y.N.U.) Lower Carboniferous. Leader, Mr. J. G. Goodchild, F.G.S.
10. Askern. (Y.N.U.) Leader, Mr. J. W. Stather, F.G.S.

TRANSACTIONS.

The Transactions, Part VIII., is now in the hands of the printer, and will be issued to the members as early as possible.

LIBRARY.

The Council have pleasure in acknowledging the receipt of the following works for the Library, mostly in exchange for the Transactions of the Association.

Report of the Australian Museum, 1891, 1893.

Record of the Australian Museum, Vol. II., Nos. 1, 2, 3, 4, 1892.

Leeds Philosophical and Literary Society. Annual Report, 1891-92.

Transactions of the Manchester Geological Society, Vol. XXI., Parts 18, 19, 20; Vol. XXII., Parts 1 to 8, 1892.

Annuaire Géologique Universel, Vol. VIII., Parts 1, 2, 3, 4, Paris, 1892 & 1893.

Transactions of Leeds Naturalists' Club, Vol. II., 1890.

Proceedings of the Liverpool Geological Society, Vol. VI., Part 4, 1892.

Annual Report of Cambridge Library Syndicate, 1892.

Transactions of Geological Society of Australasia, Vol. I., Part 6, 1892.

Hints for the Guidance of Observers of Glacial Geology, by P. F. Kendall, F.G.S. (presented by the Author).

Transactions of the Geological Association—Redcar and Bridlington. Blake, 1891. (Presented by Upfield Green, Esq.)

Proceedings of Royal Society of Tasmania, 1891.

Journal of the Manchester Geographical Society, Vol. VII., Nos. 7 to 12, 1892.
Vol. VIII., Nos. 1 to 3.

Transactions of the Yorkshire Naturalists' Union, Part 17, North Yorkshire, by J. G. Baker. Part 18, Yorkshire Carboniferous Flora, by R. Kidson, F.R.S.E., F.G.S., 1892.

Proceedings of the Geologists' Association, London, Vol. XII., Parts 9 & 10.
Vol. XIII., Part 2, 1893.

United States Geological Survey—Mineral Resources. D. T. Day. 1892.

Transactions of the Wisconsin Academy of Sciences, Vols. IV., V., VI., VII., VIII.

Report of the British Association, Edinburgh, 1892.

Annals of British Geology. J. F. Blake. 1891. (Purchased).

Report of the Smithsonian Institution, U.S. National Museum, 1889-90.

GENERAL.

The Council regret the loss, by removal from the district, of two of its prominent members. Mr. Charles Brownridge, F.G.S., the Vice-President of the Association, and one of its most active workers, received an appointment early in the year as Borough Surveyor of Birkenhead. Mr. E. R. Waite, F.L.S., about the same time, was appointed by the Government of New South Wales to a post in the Australian Museum, Sydney. In each case a hearty vote of congratulation was passed, with sincere regret at his severance from the active work of our Association.

In conjunction with the Leeds Naturalists' Club, and the Yorkshire Naturalists' Union, our Association joined in a presentation to Mr. Waite of an illuminated address and a purse of money, which were presented at a social tea and meeting of the subscribers, presided over by His Worship the Mayor of Halifax (Ald. J. W. Davis, F.G.S., F.L.S., F.S.A.)

To fill the vacancies thus created, Messrs. J. H. Howarth and J. J. Wilkinson were elected members of the Council at the February Meeting.

ADDENDA: December, 1893.

The Editor sincerely regrets that, owing to unforeseen delays in obtaining the full text of two of the papers, it has not been possible to publish this part of the Transactions so early as was expected, and he must crave the kind indulgence of the members. The lateness of the issue renders an addition to the Report necessary, if only to make a regretful reference to the unusually heavy losses sustained by the Association during the summer and autumn of 1893. In July the geologists of England were saddened by the unexpected and untimely death of Mr. James W. Davis, F.G.S., F.L.S., F.S.A., of Halifax, one of our Honorary Members, whose industrious work had done so much to make known the geology of Yorkshire, and the value of whose researches on fossil fishes was widely recognised. Following him very quickly our old friend Mr. William Cheetham, F.G.S., passed away last August at a ripe old age, up to the very last maintaining an unabated interest in the work of this Association. Just as the last sheets were passing through the press the sad intelligence was received that Mr. Cheetham's life-long friend, and an old member of our Council, Mr. Thomas H. Gray, had also been removed from our fellowship by death. The loss of such enthusiastic and vigorous workers is a serious blow to this Society, but in order that our work may not suffer, increased effort will be required on the part both of Officers and Members, so that the Association may continue in the future to prosper as heretofore. W.L.C.

PAPERS

READ BEFORE THE

Leeds Geological Association,

SESSION 1892-93.

OCTOBER 20TH, 1892.

At the opening meeting of the new session there was a good attendance of the members and their friends. Light refreshments were kindly provided by the President, and interesting collections of specimens were exhibited by the President and Mr. A. Farrar, Junr. After a short time of social intercourse, the President of the Association (Mr. JOHN INGLEBY) gave his inaugural address on

"CORALS AND CORAL ISLANDS."

(*Abstract.*)

After some references to the prospects of the Association during the coming winter, Mr. Ingleby said that in looking round for a subject on which to write a paper, his thoughts had naturally turned to the Tropics, in which he had spent some years; and, whilst not professing to have made a special study of corals, he had seen the fringing reefs of Ceylon, and also, from a distance, the mysterious Maldive Islands and the coral reefs of the Red Sea.

The coral polype is an animal low down in the scale of life, most nearly allied in our northern clime to the sea anemone, which may be often seen on our rocky coasts at low water. The body of the sea anemone consists of a somewhat cylindrical sac, usually fixed to some solid object at its base, while the mouth occupies the centre of the opposite end of the cylinder, and is surrounded by a circle of tentacles. These anemones are not coral-building animals, but there exist even in our own waters, at considerable depths, similar animals, which have the power of separating the carbonate of lime from sea-water, which they deposit in the lower parts of their bodies to form solid bases by which they become permanently fixed to the sea bottom. These solitary polypes produce large numbers of eggs, which float away and give rise to new individuals. When the animals die, their soft parts decay, and are washed away, leaving the hard skeletons to accumulate, and, in time, to become consolidated into limestone deposits.

True reef-building corals differ in several ways from these deep-water species. They cannot live in deep water, and multiply chiefly either by division, each part becoming in its turn a perfect

polype, or by budding, forming great branching masses of coral, or more compact colonies, such as that of the brain coral. By continued growth these form coral tracts, which may be likened to submarine forests. Fragments of coral, shells, and sand are time after time added to this mass, filling up the lower interstices as the branching corals grow. This porous mass is subsequently cemented by carbonate of lime into solid rock, from which the growth still continues upwards.

The growth of these corals is always most vigorous where the breakers are strongest, and this has an important bearing on the form which coral reefs assume. The wonder is that these delicate structures can withstand the force of the monsoon storms which batter away at them for months together with a force and persistency little known in these northern latitudes.

Every one is acquainted with the beautiful forms of tropical corals; but to understand their beauty one must try in imagination to clothe these skeletons with a coloured, jelly-like substance. Here you have enormous stags' antlers with hundreds of twigs, covered with numberless minute pores, and out of each pore peeps a little polype, its petal-like tentacles gently swaying in the watery breeze. Other forms are less branching and more solid. Every variety of form and colour is there. To this garden of marine flowers add hundreds of other fantastic creatures. "Nothing so odd, nothing so gay, ever entered into a poet's dream as you may find in this fairy land."

Dr. Haeckel, who paid a visit to Ceylon whilst Mr. Ingleby resided there, was particularly struck with the corals found at Galle. He speaks of them as being conspicuously and strikingly coloured; rose-coloured, red, yellow, brown, violet, etc. He says, "but if the eye is enchanted merely by the lovely hues of the coral "reef and its crowded population, it is still more delighted by "the variety of form displayed by these creatures. Just as the "radiated structures of one individual coral polype resembles a "true flower, so the whole structure of the branched coral-stock "resembles the growth of plants, trees, and shrubs. These coral "gardens display indeed a lovely and truly fairy-like scene as we "row over them in a boat at low tide, on a calm sea. It is not "from above, however, that the coral reef displays its full beauty; "on the contrary, it is essential that we take a plunge into the "sea. The diver is in reality in a new world. There is a whole "multitude of singular fishes, crustacea, mollusca, radiata, worms, "etc., whose food consists solely of the coral polypes. The "Oceanides under whose protection these coral fairy bowers of "the sea flourish, threaten the intruding mortal with a thousand "perils. Medusæ, which float amongst them, burn him wher-"ever they touch, the sting of the Synanceia is as painful and

"dangerous as that of a scorpion. Crabs nip his tender flesh, "black sea-urchins thrust their foot-long spines, covered with "fine prickles set the wrong way, into his feet and break off. "Never in my life have I been so gashed and mangled as after a "few days' diving and coral fishing at Galle, and I suffered for "weeks after in consequence."

Coral reefs are generally divided into three classes:—Fringing or Circling reefs, Barrier reefs, and Atolls. Fringing reefs are simply fringes of coral attached to existing land. Barrier reefs, on the other hand, are not continuous with the shore, but stand off at some distance, and have a channel of smooth water intervening. The depth of this channel is not great as a rule, but outside the reef there may be very deep water. Atoll reefs stand out alone in mid-ocean, without any land near them.

The upward limit of coral growth is determined by the water-level at low tide. In clear water living corals may generally be seen at eight fathoms in great masses, whilst at ten fathoms the masses stand somewhat apart, with patches of white coral-sand between. At a greater depth these patches become united into a smooth, steep slope, without any living coral. The downward limit of growth is about twenty fathoms, though Dr. Guppy mentions cases where live corals have been found at a depth of 50 to 60 fathoms. The area in which coral reefs are found is restricted to a zone of water which does not fall below 68 deg. F., but they are by no means equally distributed through this zone. Wherever great rivers debouche they are absent. The sediment brought down by fresh water invariably interferes with the growth of corals. The Bermuda Islands, in lat. 32 deg. 15 min., seem to have been the points farthest removed from the Equator at which Darwin found them. There are, however, large areas in the Central Pacific where, strange to say, the islands are perfectly free from fringing reefs. Volcanic action, Darwin thinks, may have something to do with their absence.

Atolls are very different from fringing reefs. Instead of being attached to adjacent land they rise abruptly up in mid-ocean from great depths. The appearance of these islands as seen from the deck of a ship differs very little from that of any tropical coast. A fringe of vegetation behind a white beach is all that can be seen without closer inspection. If, however, we crossed these islands we should observe a ring of vegetation with water inside and outside connected by a channel through the reef, or a chain of such islands with a channel between each and its neighbour.

The inner lagoon may be from five to twenty fathoms deep. These islands are not always covered with vegetation, and often are composed of ring-shaped basins of coral rock having the outer edge just at the level of the sea. These atolls vary in diameter

from a mile or less to ninety miles along the longer axis. As a rule the larger atolls are not nearly so circular as the smaller ones.

Chamisso, nearly one hundred years ago, thought that the basin-like lagoons of atolls were due to the natural growth of the coral on the tops of submarine mountains, the more vigorous growth on the outside producing the encircling ring. Growth in the lagoon, he thought, was hindered by coral debris, sand, shells, etc., swept over the outer edge by the waves. The frequent occurrence of volcanic islands in the Pacific Ocean led other investigators to suppose that atolls were formed on the crests of sub-marine volcanic craters. Even the cautious Lyell admitted that this might be the case. Darwin, during his voyage in the Beagle, was struck with the remarkable appearance of these coral reefs, and especially with the atolls. When he found these curious formations repeated over and over again in every variety over thousands of miles of ocean, he could not bring himself to believe that there had been rocky elevations scattered over this vast area all of exactly the proper height for the coral polypes to flourish. After carefully pondering the question he came to the conclusion that subsidence alone would explain all the phenomena. Briefly, he considered that each atoll had passed through the successive stages of fringing and barrier reefs as the island was gradually submerged, the growth of the coral near the land being hindered by fresh water laden with detritus, whilst the outside of the reef was exposed to the fresh surf which is its very life. In time the island would be entirely submerged the reef alone keeping its head above water and forming a true atoll. It was in 1837 that Darwin put this theory before the public and it took the whole scientific world by storm. In 1851 Agassiz expressed the opinion that Darwin's theory would not account for the Florida reefs; in 1868 Semper concluded that reefs were due not to subsidence, but to complex co-operation of coral growth with the waves and currents of the sea. Dr. Rein followed with his observations on the Bermudas, which he considered were built up on a submerged plateau.

In 1880 Dr. Murray gave an abstract of his observations during the voyage of the Challenger. The theory he advanced was one of elevation. He considered the coral islands, with few exceptions, to be of volcanic origin, and that the erosive force of the waves had reduced the more prominent peaks and ridges to the lower limit of breaker action, thus forming a submerged platform, suitable for corals to build upon. On the other hand submarine eminences too low down for the polypes to build on, may have been raised by the deposition of organic matter to the proper level. So abundant is the pelagic life in tropical seas that Dr. Murray estimates that in a square mile of such water, taken

to a depth of 100 fathoms from the surface, there is, in the form of calcareous shells, more than 16 tons of carbonate of lime. These hard parts are continually forming a deposit on the sea beds, and, as the organisms are most plentiful in shallow water, submarine mountain peaks would be most favourably situated for their accumulation. Shoals also have the effect of forming tidal currents which sweep off the looser deposits and so prepare the surface for the reception of deep-sea corals, sponges, and such-like organisms. The upward growth would be accelerated by the accumulated remains of this more abundant fauna. In the course of time this platform would be raised to a height suitable for the growth of the coral polypes, and would grow slowly up in a rounded knoll until the surface of the water was reached. If such a shoal were elongated and lay off the coast of a continent or island we might have a barrier reef formed directly by this process; or, if the platform had been the crater of an extinct volcano, we might have an atoll formed without going through the stages required by Darwin's theory. Dr. Murray explains the process thus :—The outer margin of a clump of coral would have the advantage of the more abundant supply of food brought by the surf, and would grow outwards. But as the whole available area of the foundation is already occupied, and as the coral cannot creep down into the deep water outside the shoal, it simply contiuues to grow outwards without any support until it is broken off by the action of the waves. In this manner there is built up a talus of its own debris around the central shoal. As this wall of dead coral reaches the proper height the living coral will take possession of it, and continue the building upwards and outwards.

To explain the formation of an atoll on this theory we must return to our theoretical coral-knoll. The central convex portion would first reach the surface and by exposure to sun and air, the collection of organic matter upon it, and the protection from the surf which contains its food, the coral dies. Rain water collects and by its solvent action, aided by carbonic acid and greatly increased by the high temperature, a hollow is formed which in time becomes the lagoon. Debris from the reef itself, or drifted from some other place, together with seeds and insects, are now thrown upon the incipient atoll and ere long a ring of vegetation springs up.

Whether the explanation advocated by Murray and Guppy is destined to lead to the total collapse of Darwin's hypothesis is likely to remain for some time an unsettled question. Some writers hold that while Murray's view may be the true explanation of many atolls and barrier reefs, it does not forbid the possibility that many reefs may be formed as Darwin supposed. Nor did

Darwin insist that his theory fully accounts for all reefs. He said, "Well characterized atolls or encircling reefs, where several occur together in a group, or a singular barrier reef, if of large dimensions, clearly indicate a movement of subsidence. The evidence from a single atoll, or from a single encircling reef must be received with caution, for the former may be based upon a submerged crater or bank, and the latter on a submerged margin of sediment or worn-down rock."

Dr. Geikie, whilst opposed to the subsidence theory, does not think that the solvent action of carbonic acid is sufficient to account in all cases for the exceptional depth of some of the lagoons. He thinks it not impropable that in some few cases lagoons may owe their great depth partly to subsidence.

The President's paper, which was splendidly illustrated by specimens and lime-light views, was followed by an exhibition of new lantern-slides, including a splendid series taken on the Dorsetshire coast by Mr. Godfrey Bingley, views taken on the recent excursion to Brimham, by Mr. Gurnell, and some fine Swiss pictures, chiefly in the Zermatt region, kindly lent by Mr. Robert Scott.

The proceedings closed with hearty votes of thanks to the President for his interesting address, and to the gentlemen who had lent the slides.

NOVEMBER 17TH, 1892.

Mr. JOHN INGLEBY, the President, in the Chair.

"CHALK AND FLINT,"

By Mr. C. D. HARDCASTLE.

Chalk and Flint are so intimately associated in the position in which they are found in nature, and in their probable origin, that no apology is needed for treating of the two in one paper. Chalk is a pulverulent soft white or grey limestone, but varying in degrees of hardness and colour, from a loose-bedded earthy mass to a flaggy and compact stone adapted to building purposes, and from an almost pure white to dull dark grey and red. It consists almost entirely of carbonate of lime. Flint is nearly pure silica and occurs chiefly in nodular, but occasionally in tabular layers, embedded at intervals, in the direction of the stratification of the chalk, and also in other directions along joints and fissures. The Chalk formation is usually divided into Upper, Middle and Lower Chalk and Chalk Marl. The Upper Chalk generally is the softer and contains layers of flint plentifully. The Middle Chalk is somewhat harder and contains much less and

sometimes scarcely any flint. In the Lower Chalk, which is harder still, flint is absent. Below these occur beds of Chalk Marl, Chloritic Marl, Greensand and Gault. By the earlier geologists this series from the Upper Chalk to the Gault inclusive, was denominated the Cretaceous Formation.

Sixty years ago Sir Henry de la Beche suggested that as the series of changes which culminated in the conditions under which the Upper Chalk was laid down, commenced at the close of the Oolitic period, the Wealden formation—a series of sands, clays, etc., which intervenes between the Oolitic or Jurassic and the Chalk formations—should be included in the Cretaceous series. Sir Charles Lyell adopted the suggestion and now the Wealden and Chalk are generally included in the Cretaceous Series, although there is no real chalk—Creta—below the Chalk Marl. By Prof. Prestwich and Sir A. Geikie the Wealden is called the Lower, and the beds from the Gault to the Upper Chalk inclusive, the Upper Cretaceous series.

The Extent and Limit of the Cretaceous Formation.

In 1849 Leopold von Buch gave the limits of the Cretaceous formation, as Ireland—Rathlin Island near the Giant's Causeway 55 deg. 20 min., Thistedt in Jutland 57 deg., Flamborough Head in Yorkshire 54 deg. 10 min., Grodno in Russia 54 deg., and Orel a degree and a half south of Moscow, *i.e.*, 54 deg. On the Ural river 51 deg. 30 min. Limited on the East by the Mirchodjar Mountains 75 deg. E. long. Beyond the ocean the limits given are New York nearly 40 deg. N. lat., Kentucky and Tenessee 37 deg. In Western America, on the Sioux river 50 deg. of latitude, or fully 10 deg. higher than in Eastern America. In South America he says Darwin found Cretaceous fossils in abundance in strata as far South as Mount Tarn, at an elevation of 2,000 feet, in the Straits of Magellan in 53 deg. of S. lat. The small extent towards the poles, he says, which the Chalk formation attains, compared with the Jurassic Strata and still more with the Palæozoic deposits, has been regarded by Dr. Boué, not without some probability, as the most ancient known effect of the influence of climate on the faunas of former worlds.

The Cretaceous system of the Old World, here and there covered by more recent strata, is divided into two series, varying considerably in petrological structure, and also in the character of their fossil remains, in Europe by a series of ridges or mountain ranges, including the mountains of Central France, the Vosges, the Black Forest Mountains, the Hartz, Erz-Gebirge, Sudetic, and Carpathians, and so on to the Crimea and the Ural river and mountains. The series is continued eastward through Asia, southern and central India, to China, but the distinctions are less

marked. In Europe, the northern division contains the typical white chalk with which we are at present more particularly concerned, while the southern consists of sandstones and more or less compact and consolidated limestones.

In Great Britain the Chalk occurs on the N.E. coast of Ireland, in Antrim and Londonderry, where it is partly concealed by basalt by which it has been materially altered. It only occurs in Scotland in one or two of the Western Isles as Mull and Morven. The English system commences in East Yorkshire south of the Vale of Pickering, sweeps round in a somewhat semi-circular form, from the shore near Speeton in Filey Bay by Hunmanby, Winteringham, Aclam and Market Weighton, to North Ferriby and Hessle on the Humber. The district thus enclosed comprises the Yorkshire Wolds and the plain of Holderness. The Chalk as exposed covers an area of nearly 400 square miles, and is 600 feet thick. The highest points are Wilton Beacon 805 feet, Hunsley Beacon 531 feet, and the cliffs above Speeton 450 feet. The eastern escarpment of the Wolds marks the position of an ancient sea cliff, which passes through Bridlington, Driffield, Beverley and Cottingham to Hessle (*Memoirs: Geology of Holderness)*. The Wolds are continued beyond the Humber through Lincolnshire to the Wash, beyond which it covers Norfolk and Suffolk, though largely concealed by drifts. Thence it runs through Cambridge, Herts., Bucks., Berks., and Wilts., to Dorset on the south coast. From Wilts. eastward the chalk runs in two directions, north-east through Hants., Surrey and Kent, to Folkestone, Dover, Ramsgate and Margate, forming the North Downs; and south-eastward through Hants. and Sussex, forming the South Downs. An anticlinal brings up the Wealden beds between the two ranges.

This Chalk System is continued across the Channel to Belgium and the north of France, three prominent synclinal flexures being observable, two containing Tertiary deposits of a somewhat different character, and the other exposing the Chalk, viz: the London basin and London Clay, the Boulogne basin exposing the Chalk, and the Paris basin with its sands, marls, and gypsum beds, encircled by a broad band of true chalk.

Divisions and Subdivisions.

The whole of the Cretaceous system has been divided into the Upper and Lower Cretaceous; the Lower being sub-divided into the Wealden and Lower Greensand; and the Upper into Gault, Upper Greensand, Chalk Marl, Lower Chalk or Chalk without flints, Chalk with few flints, and Chalk with numerous flints. The beds above the Upper Greensand to which the word Chalk has been popularly applied, have been divided also into Upper Chalk with many flints, Middle Chalk with few flints, and

Lower Chalk without flints including the Chalk Marl. This tripartite division is now generally adopted, Upper, Middle, and Lower Chalk, disregarding the arrangement depending on the occurrence or non-occurrence of flint. During the past thirty years the Chalk formation has been carefully studied both in England and on the Continent, resulting in the discovery that natural lithological divisions exist each containing its characteristic fossils by which it may be readily recognized, the softer chalk being separated by harder bands, three of the most prominent of which are the Chalk Rock separating the Upper and the Middle Chalk, the Melbourn Rock between the Middle and the Lower Chalk, and the Totternhoe Stone above the Chalk Marl. By means of these three bands the Chalk of the south of England is divided into four stages, the Totternhoe Stone sub-dividing the Lower Chalk. In the whole series ten palæontological zones have been recognized in which the fossil remains help to distinguish the beds; and by means of which the succession of the faunas can be traced.

This zonal arrangement was first made by Dr. Barrois and Professor Hébert for the Chalk of France, and was applied by Dr. Barrois to the English Chalk, and has since been more fully worked out by Messrs. Penning, Jukes-Browne and others for different localities. The French professors divide the Chalk into three stages so far as they correspond with the English system, viz: Senonian, Turonian, and Cenomanian, the equivalents of the Upper, Middle, and Lower, corresponding as nearly as may be.

The zones as worked out in Cambridgeshire and given by Mr. A. Jukes-Browne in a paper in the Geological Magazine for 1880, are as follows:—

UPPER CHALK.
1. *Zone of Micraster corbovis.*
2. Chalk Rock.

MIDDLE CHALK.
3. *Zone of Holaster planus.*
4. *Zone of Terebratulina gracilis.*
5. *Zone of Rhynchonella Cuvieri.*
6. Melbourne Rock.

LOWER CHALK.
7. *Zone of Holaster subglobosus.*
8. Totternhoe Stone.
9. *Zone of Rhynchonella Martini.*
10. Chalk Marl and Cambridge Greensand.

The following table represents the zonal arrangement of the Yorkshire Chalk which differs materially from that of the Midland and Southern districts:—

UPPER CHALK—Senonian.
1. Soft Chalk without flints.
Zone of Belemnitella mucronata, Marsupites and Sponges.

2. Chalk with flints.
Zone of Micraster cor-anguinum.
LOWER CHALK—Turonian.
3. Chalk with nodular flints.
Zone of Inoceramus mytiloides.
Cenomanian.
4. Grey Chalk without flints.
Zone of Holaster sub-globosus.
GAULT—Albian.
5. Red Chalk.
Zone of Belemnites minimus.

The Yorkshire Chalk differs in several respects from that of the south of England. It is as a rule much harder and of a more flaggy character, and many fossil species common in the south are totally wanting in the north. The opinion is becoming prevalent that although the two series may have been produced under different conditions, there is a greater affinity between the northern Chalk fauna and that of north-west Germany than with the fauna of the southern counties, which agrees rather with that of northern France. Probably the Chalk of the northern counties York, Lincoln, and Norfolk, and that of north-west Germany was laid down in an inland sea, deeper than that in the southern Anglo-French basin, which was probably shallower and more exposed to and connected with an open sea or ocean similar to the present Atlantic. The Red Chalk of Speeton, Hunstanton and other parts of Lincolnshire, agrees in fauna with the totally different beds of Gault and Greensand of Folkstone, &c. Mr. Mortimer, of Driffield, some thirty years ago drew attention in the "*Geologist*" to a peculiar striated structure or marking in the Yorkshire beds, occurring generally in districts where the Chalk had been disturbed or subjected to pressure. It very much resembled slickensides, and was supposed to have been produced by the sliding of surfaces one over the other.

The maximum thickness of the Cretaceous rocks for the south of England has been estimated at 4,100 feet according to Jukes-Browne. The Upper Cretaceous—Senonian—or Upper Chalk 600 ft., Turonian or Middle 250 ft., Cenomanian or Lower 200 ft., Upper Greensand and Gault 250 ft.=1,300 ft. Lower Cretaceous, Lower Greensand 800 ft., Weald Clay and Hastings Sand 2,000 ft.=2,800 ft. The estimates from various authors for different typical localities are—Isle of Wight, Upper Chalk 1,200 ft., Lower 200 ft., Chalk Marl 80 ft.,=1,480 ft. Kent, Upper Chalk 560 ft., Lower 140 ft., Chalk 210 ft.=910 ft. Norwich neighbourhood, 1,150 ft., Yorkshire, Upper Chalk 490 ft., Lower 200 ft., Grey Chalk 70 ft., Red 30 ft.=790 ft. Some estimates make the White Chalk about 660 ft., or in round numbers 700 ft. Under London, where the Upper divisions are absent, the Chalk averages about 650 ft., exclusive of the Upper Greensand which averages about 30 ft.

Life of the Cretaceous Period.

The fossils of the Wealden beds are such forms as live in fresh water, while those of the Lower Greensand are purely marine. The break between the Lower and the Upper Cretaceous is marked by a great divergence between the fossils of the one and the other, little more than one-sixth of the Lower Cretaceous fossils having survived to the Upper Cretaceous period. Among the more abundant characteristic fossils of the Chalk are, *Foraminifera*—Globigerina and Rosalina. *Spongida*—Siphonia, Cheonites, Ventriculites. *Bivalves*—Terebratula, Inoceramus and Spondylus spinosus. *Cephalopoda*—Belemnites and Turrilites. *Echinodermata*—very plentiful, and many genera confined to the Cretaceous period. Ananchites, Discoidea, Galerites, Micraster and Marsupites; also Holaster and Goniaster. Fishes and reptiles are also fairly represented.

Origin of the Chalk.

The sands, clays, and shales of the Lower Cretaceous series are doubtless ordinary sedimentary deposits of materials denuded from different areas and deposited under varying circumstances during periods of oscillation of the land, partly by direct deposition and partly by chemical precipitation. It was long ago surmised, however, that the Chalk could not have been so deposited. Eminent microscopists have proved that it consists to a very large extent of the shells whole or comminuted of minute organisms, Polyzoa, Foraminifera, &c., and fragments of shells of larger size Mollusks, Encrinites, Corals, &c.

These various organisms, it is well known, have the power of secreting, some of them carbonate of lime, others silica, or both, held in solution in sea water, to form outward shells for covering and protection or internal structure for support. Of these shells and structures microscopists and chemists agree that the white Chalk of some localities is almost entirely composed, and all other Chalk to a very large extent. Some of the very minute forms of life found in the Chalk are Coccoliths, Rhabdoliths, Diatoms, and Radiolaria; larger ones Ceripora, Idmonea, and Retopora, and of Foraminifera, Cristellaria, Globigerina, Rotalia, &c.

The opinion prevailed some time ago among certain geologists that the whole of the Chalk, as well as many other limestones, was produced by organic agency in the way indicated above. This opinion, formed chiefly as the result of the microscopic examination of thin slices, has lately undergone modification, the examination of washed chalk showing indications of finely disseminated mud which cannot be traced to the trituration of shells, corals or encrinite stems. It is probable that all Chalk

contains more or less amorphous lime produced by trituration of older rocks or by chemical precipitation.

When, as the result of the deep sea dredgings, commenced in 1857 to ascertain the nature of the bed of the Atlantic previous to laying the Atlantic Cable, it was found that the deepest portions of the sea were covered with a white, grey calcareous mud containing Globigerina and other minute organisms, similar to those of which to a great extent Chalk consists, many scientists came to the conclusion that the deposition of the chalk had not ceased but was being continued at the present, and Sir Wyville Thompson and others contended that not only was a chalk formation proceeding, but that *the* chalk formation with its fauna was still in operation, and long articles were written on "The Continuity of the Chalk."

These conclusions, however, have not been confirmed by recent analysis and investigation, either with respect to the composition of the deep-sea ooze, and the Chalk, or the fauna which they include. After a careful consideration of the question Professor Prestwich says, "In no period of the past do we find deposits exactly of the character of the abyssal 'red clay' and 'Globigerina Ooze,' nor do we meet at the present day with the exact homologue of the Chalk."

FLINT.

Flint is a variety of quartz consisting of a mixture of insoluble crystalline silica, and amorphous silica, soluble in caustic potash and other alkalies, with a slight mixture of lime, alumina and oxide of iron. Some specimens give 99 per cent. of silica, ·5 per cent. of lime, and ·25 per cent. of alumina and oxide of iron each, and a little carbonaceous matter which gives the dark colour to the black flints. Flint occurs in nodules and tabular layers in the Upper Chalk of the South of England. In Yorkshire the layers of flint occur in the lower portion of the Upper Chalk, but it is not easy to correlate the Northern with the Southern Chalk strata. According to some authorities, the Upper Chalk throughout England where not much denuded is flintless at the top to a greater or less depth, and that in Yorkshire the flintless portion of the Upper Chalk is thicker or deeper than in the southern districts.

Flint is a hard, tough substance, breaking with a sharp cutting edge, so as to render it easily adaptable for implements of war and for domestic use in what have been called pre-historic times. In the Stone Age the principal weapons and articles for cutting purposes were made of it; as axes, lance-heads, arrow-heads, knives, saws, awls. Flints are brittle when first quarried, but become tough and durable on exposure. The lighter coloured flints are translucent throughout in thin slices, the darker ones only so on the edges.

Large pre-historic manufactures of flint implements have been discovered at Pressigny in France, and Cissbury and Brandon in England, where implements were manufactured on a large scale in the pre-historic and newer Stone Ages. At Brandon the manufacture of gun-flints is still carried on, the flints being sent to Brazil and the East. Flints were formerly used for fire-arms everywhere, and some of us are old enough to remember the general use of flint, steel, and tinder and the old sulphur match for the purpose of procuring light. Many a time have I experienced the difficulty of procuring a light on a dark, cold frosty morning with the old tinder-box.

Flint—Theories respecting its Origin.

"It is generated of earth and of much sulphur," Lovell 1661, "The Universal History of Minerals."

Hill, 1746, in notes to his translation of "Theophrastus' History of Stones" says:—"The flint and pebbles we now everywhere see, were all formed in the waters of the Deluge, by the mere afflux of their constituent matter."

Bakewell, 1813, cannot but think that lime and flint are convertible into each other by natural processes. He also says that it is not improbable that siliceous earth may have permeated the lime and have been afterwards separated by chemical affinity, and collected in fissures and cavities of the calcareous rock.

Wm. Phillips, 1816, enumerates the following opinions held at that date. (1). Flints occupy hollows formerly occupied by animals, affinity between silica and the animal matter resulting in the formation of flint. (2). The lime or chalk is converted into silex by some unknown natural agency. (3). Flints are formed by the infiltration of siliceous matter through the chalk. Sir H. T. de la Beche, 1834, says, "The silica appears to have separated out of the great mass of calcareous matter, and to have arranged itself in numerous instances round various organic matters, and some determining cause, though not necessarily an organic remain, must have produced the accumulation of siliceous matter in a particular point; and this cause must have extended in lines parallel to the general stratification."

Sir Chas. Lyell in the first edition of his "Elements of Geology," 1838, expresses the belief that microscopic infusoria can give rise to dense masses of pure flint from the solution of their siliceous skeletons or cases, and that the siliceous framework of the sponges and other silex-secreting zoöphytes, also contribute to its formation; and in later editions he accounts for the supply of silica by the quantities of decomposed felspar (which contains a large proportion of silica) which is being continually carried by the rivers into the sea.

Dr. Mantell supposed that the nodules of flint were produced by the agency of heated waters holding silica in solution precipitated in some way or other into the basin of the Chalk formation before the chalk was consolidated, and contended that the organic bodies served as nuclei or centres round which the silex concreted. Many observers are of opinion that the nodules and layers of flint owe their origin to the sponges, some believing that all flints have been sponges. Both the tabular and nodular layers of flint appear to occupy the position of beds of sponges, and many sponges and other organic bodies are found filled with or incased by flint.

There is, however, great diversity of opinion as to the manner in which the concretions have been produced; there is undoubtedly a large amount of silica held in solution in sea-water, which is secreted by the minute animalculæ as shields or coverings and by sponges and other zoöphytes for external or internal structure. After their death the silica is dissolved and deposited on the ocean floor; this deposit receives accessions by direct chemical precipitation until a thick stratum is deposited. In the cases of the sponges and other siliceous organisms the flint was secreted directly, but in those instances where flint occupies the place of the shell or internal portions of sea-urchins, corals, etc., the silica has apparently been substituted for the original carbonate of lime by a process of chemical pseudomorphism, *i.e.*, as the carbonate has dissolved, silica has by slow degrees taken its place, after or during the formation of the limestone. Prof. Sollas's theory is that the siliceous spicules of sponges, the cases of diatoms, &c., accumulating in the chalk ooze, under great pressure in sea-water, enter into solution as organic silica; that in places where the sponge growth is considerable, sufficient silica is added to the solution to concentrate it sufficiently for the deposition of mineral silica, which replaces a considerable portion of the calcareous ooze or mud producing siliceous chalk; and then the remainder of the calcic carbonate is replaced by further depositions of silica, until the siliceous chalk is converted or changed into flint. Admitting this, there is still some difficulty in accounting for the absence of silica between the successive layers of flint, and various attempts have been made to explain the matter, and also to account for the presence of flint in cross veins and perpendicular fissures of the chalk. It is generally supposed that after the deposition of the beds, the silica in solution aggregated by a kind of dyalizing process or endosmose, the colloid or gelatinous silica separating from the calcareous or other matter with which it was combined, and aggregating in layers and afterwards by contraction of the gelatinous silica forming into nodules. Dr. Wallich accounts for

the accumulation of silica in tabular layers by the presence of sponge protoplasm, an excess of which is said to be found about thick beds of sponge. This gelatinous organic matter being of less specific gravity than the calcareous mud rises through and floats on the top of it. That the shells of siliceous organisms and the spicules or frame-work of decayed sponges rest and accumulate on it, and are dissolved by its chemical properties, thus producing colloid silica, which, as it dries or stiffens under heat and pressure, contracts and shrinks into nodular forms under favourable circumstances, or remains in one tabular mass.

The sponge protoplasm alluded to is what Prof. Huxley thought to be a distinct organism spread in mass over the sea bottom, and to which he gave the name of Bathybius. It is the living organism; what we know as sponge being only the framework which supports it—its bones, so to speak.

Messrs. Penning and Jukes-Browne make suggestions as to the occurence of flints in regular layers on somewhat similar lines to Dr. Wallich's theory ("Memoirs of the Geology of the neighbourhood of Cambridge"). They assume that the chalk was deposited as a soft calcareous mud, at least half of which consisted of silica, equally distributed throughout the water by which the unsolidified portion of the mass was permeated; that organic remains in various stages of decomposition were at particular periods strewed on the surface of this mud, and that some kind of chemical action was set up by which the silica was precipitated or deposited upon and in the same plane as the decaying organisms, the mud continuing to be deposited until the bed of flint thus formed was buried. They also assume that the force by which the silica is attracted, would act upwards and downwards through some definite thickness of the mud, and that until the sediment attained a certain height above the line the silica would continue to segregate along it, and in and around its organisms; when that point was reached, no more silica would segregate along that particular zone, the organic remains on the then existing floor would in a similar manner serve as the nuclei of a new layer, and another line of flints would be at once commenced.

Some authors are of opinion that flints are formed in the same manner as the nodules of septaria, cement stones, ironstones, coal balls, &c., are formed in sandstones clays and shales, and this is in all probability the case. This was well elucidated in a paper read by Mr. Holgate on the subject some years ago. The nodule has frequently, not always or necessarily, some foreign body as a nucleus, and appears to have been formed on the same principle by which crystals are formed in saline solutions, by the dropping in of some foreign substance, but more readily by a crystal of the salt itself.

Before leaving this subject we may just allude to a theory propounded by the Rev. W. B. Galloway, but which has had no countenance from scientists. He contends that the chalk and flint formation is not of organic but meteoric origin; that both were produced together by periodical meteoric showers, the chalk of meteoric dust, and the flints of similar material changed or metamorphosed in their transit; and that the organisms in the chalk are accidental and only occur where the dust fell into the sea and mingled with them in the sea bottom.

The Lecturer exhibited specimens of varieties of the Cretaceous rocks from the Wealden to the fine white Upper Chalk, including the altered chalk and flints of Antrim. Also numerous fossils, casts, &c., in chalk and in flint from various parts of England. Chalk sponges and flint ones, one or two fine specimens showing how the flint replaces the chalk which originally took the place of the organism by infiltration. Some of the Echinoids, Micrasters, Ananchytes, &c., were filled with chalcedony and others with well defined crystals of quartz. Flint nodules containing sponges, and others with drusy quartz, and some well-marked banded flints.

DECEMBER 15TH, 1892.

HOLIDAY NOTES.

Mr. WILLIAM CHEETHAM, F.G.S., in the Chair.

At the commencement of the meeting the Hon. Secretary (Mr. W. L. Carter, M.A.), read a letter from Mr. Edgar R. Waite, F.L.S., resigning his membership of the Association on account of his appointment to a post in the Australian Museum, Sydney, by the Government of New South Wales. The following resolution was moved by Mr. C. Brownridge, F.G.S., seconded by the Hon. Secretary, and carried unanimously :—

"That the members of the Leeds Geological Association congratulate Mr. E. R. Waite upon his appointment to a post in the Australian Museum; and while expressing their regret at his severance with our Association, they desire to testify their high appreciation of his services in connection with the scientific societies of Leeds, and trust that in his new sphere he may enjoy that success which he has attained in Leeds." Mr. Waite briefly responded. Mr. S. W. Cuttriss then read a paper on

"THE 'PARALLEL ROADS' OF GLEN ROY."

About twelve years ago my attention was first directed to the subject of this paper by reading in Tyndall's "Fragments of

Science" the exceedingly interesting discourse he delivered at the Royal Institution of Great Britain in 1876. I then resolved that at the earliest opportunity I would pay a visit to the "Roads" and see for myself this remarkable natural phenomenon which has been a source of controversy, especially among geologists, for many years. Circumstances had not been favourable to the consummation of my desire until the present year, when in August last I was able to arrange a most enjoyable week's tour in Scotland, devoting a couple of days to a practical study of the "Roads." Before giving you a description of my visit I will explain the character of the Terraces, and consider some of the theories advanced to explain their formation, acknowledging my indebtedness to Professor Tyndall and Mr. T. F. Jamieson, this paper being little more than a digest of their valuable contributions to the literature of the subject.

The first published allusion to the Parallel Roads of Glen Roy occurs in the appendix to the third volume of Pennant's Tour in Scotland, published in 1776. "In the face of these hills," says the writer, "on both sides of the glen, there are three roads at small distances from each other and directly opposite on each side. They are carried along the sides of the glen with the utmost regularity, nearly as exact as drawn with a line of rule and compass." The average heights of the three roads of Glen Roy are respectively 1,150, 1,070, and 860 feet above the sea. Hence a vertical distance of 80 feet separates the two highest, while the lowest road is 210 feet below the middle one. These roads are usually shelves or terraces formed in the yielding drift which here covers the slopes of the mountains. They are all sensibly horizontal and therefore parallel. Their breadth varies from 40 to 70 feet. They slope towards the valley at an angle of from 5 to 30 degs., the hill face being inclined from 25 to 40 degs. Pennant accepted as reasonable the explanation of them as given by the country people in his time. They thought the roads were designed for the chase, and that the terraces were made after the spots were cleared in lines from wood, in order to tempt the animals into the open paths after they were roused, in order that they might come within reach of the bowmen who might conceal themselves in the woods above and below. In the year 1817 Dr. MacCulloch, then president of the Geological Society, first pronounced them to be the margins of lakes embosomed in Glen Roy. Why there should be three roads, or why the lakes should stand at these particular levels was left unexplained.

In seeking for a solution of the problem two distinct mental processes are involved. First, the faithful and sufficient observation of the data; and secondly, that higher mental process in which the constructive imagination comes into play, weaving the

observed facts into an organic whole, and picturing to the mind the cause as well as the effect. Adjacent to Glen Roy is a valley called Glen Gluoy, along the opposite sides of which runs a shelf of precisely the same level on both sides. Sir Thomas Dick-Lauder followed these into the recesses of the mountains, until finally he came to a col or watershed at the head of the glen. Allowing for the considerable thickness of peat which now covers the ground, this col was found to be of the same level as the shelf which sweeps round the glen, viz., 1165 feet above the sea, or 15 feet above the highest road in Glen Roy. From this col a lateral branch valley, Glen Turrit, leads down to Glen Roy. Descending to the highest road of the latter glen, he followed it exactly as he had followed the shelf in Glen Gluoy, ultimately reaching another col looking into Glen Spey, and of the same level as the highest road of Glen Roy. He then dropped down to the lowest of these roads and followed it to the mouth of the glen. It doubled round the hills at the mouth of Glen Roy and continued along the sides of the mountains flanking Glen Spean. Following it eastwards he came to Loch Laggan, the surface of which rises almost to the level of the road, and beyond the head of this lake he found another col of the same level as the single road in Glen Spean, which, it will be remembered, is a continuation of the lowest road in Glen Roy. Here we have a series of facts of obvious significance as regards the solution of the problem. Supposing the mouth of Glen Gluoy stopped by a barrier sufficiently high, the waters from the mountains flanking the glen would collect and form a lake, the surface of which would gradually rise until it reached the level of the col at the head of the glen. The superfluous water would then discharge itself over the col into Glen Roy. As long as the barrier stopping the mouth of Glen Gluoy continued high enough we should have a lake at precisely the level of the shelf, which lake, acting upon the loose drift upon the hill sides, would form the shelf revealed by observation. So much for Glen Gluoy. Now suppose the mouth of Glen Roy stopped by a similar barrier. Behind it also the waters from the adjacent mountains would collect. The surface of the lake thus formed would rise until it reached the level of the col which divides Glen Roy from Glen Spey. The superabundant water would then flow into the valley of the Spey. The lake thus dammed in, with its surface at the level of the highest road, would act as in Glen Gluoy upon the friable drift and form the highest shelf. Now let us imagine the barrier so far removed from the mouth of Glen Roy as to establish a connection between it and Glen Spean. The two glens would then be occupied by a continuous lake, the level of which would be determined by the col at the head of Lake Laggan. The water in Glen Roy would sink to the new level corresponding

exactly with the level of the lowest road.

To account for the formation of the second or middle shelf, Dick-Lauder supposed that at a certain period in the breaking down or wasting away of the barrier, a halt occurred, sufficiently long to dam the lake in Glen Roy at a height corresponding with the middle road. This weakness in the theory was adduced by Mr. Darwin to prove that the cols did not constitute an essential feature in the phenomonen of the parallel roads. The theory was, however, re-rivetted by the discovery of Mr. David Milne-Home in 1847. On the east side of Glen Roy is the lateral valley of Glen Glaster. There is nothing in this glen to attract attention, but Mr. Milne-Home entered it and found traces of the middle and lower roads. Following up the glen a col or watershed was found of precisely the same level as the second Glen Roy road. When the barrier blocking the glens was so far removed as to open this col, the water in Glen Roy would sink to the level of the second road and form another shelf in that glen in the same manner as the other roads.

Having thus shown the important part played by the cols in determining the heights of the various roads, let us now consider the nature of the barrier blocking the mouths of the glens. Sir Thomas Dick-Lauder imagined his barriers to have been formed of vast masses of detritus which had been heaped up to a sufficient height by some unknown convulsion, but where it came from or what subsequently became of it I do not know that he attempted to offer any explanation. No such barriers as he assumed could have existed without leaving traces behind them, and no such traces are to be found. The two highest roads stop abruptly at different points near the mouth of Glen Roy, but no remnant of a barrier is to be seen. It might be urged that a subsequent invasion of the valley by glaciers had swept the detritus away, but there have been no glaciers in the valleys since the disappearance of the lakes, or the terraces themselves would have been obliterated. Taking all the facts into consideration I think we may dismiss the detrital theory as incompetent to offer a satisfactory solution of the problem. Mr. Darwin, among others, at first inclined to the notion that the sea was the active agent in forming the terraces. He imagined that the whole region was once submerged and subsequently upheaved, that there were pauses in the process of upheaval, during which these glens formed so many fiords, on the sides of which the parallel terraces were formed. The theory will not, however, bear close criticism. It will not account for the sea being 15 feet higher in Glen Gluoy than in Glen Roy. It will not account for the absence of the second and third roads from Glen Gluoy, nor the entire absence of the shelves in neighbouring glens. To what then are we to look for a solution of the problem?

Our answer is, to glaciers. Here we have a barrier which would be able to dam up the water in the glens to the necessary height, and in melting leave not a wrack behind, although fortunately there is ample evidence of their existence on the mountain sides to-day. At the time the detrital and sea-marginal theories were first advanced, glacial action was imperfectly, if at all, understood. Agassiz, in 1840, was the first to pronounce the opinion that the barriers which stopped the glens had been barriers of ice.

Let us now consider how such immense masses of ice came to be formed at the mouths of the glens, and in doing so I cannot do better than quote largely from the exhaustive contributions on the subject by Mr. T. F. Jamieson. The great collecting ground of the glaciers which dammed the glens were the mountains south and west of Glen Spean, and those north and south of Loch Arkaig. The monarch of these is Ben Nevis, 4406 feet high. The position of Ben Nevis and his colleagues in reference to the vapour-ladened winds of the Atlantic is a point of first importance. The rain-gauge on the top of Ben Nevis has yielded no less than 145 inches of water in the course of a single year, whereas at Laggan, in the upper part of Strath Spey, the average is 46, and on the shores of the Moray Firth only from 25 to 30 inches. It is also important to notice that it is during winter that the greatest precipitation takes place. We shall probably not be far wrong in assuming that during the glacial period most snow fell where is now most rain. As snow is also the mother of glaciers, here also would be the heaviest ice. The outward movement of the ice, as deduced from the glaciation of the rocks and transport of boulders, seems to have proceeded from the direction indicated. It is important to bear in mind that the lakes were formed during the decadence of the glacial period, as, at first, the ice filled Glen Gluoy and flowed out of the top, it likewise filled Glen Roy and passed out eastwards over the pass at its head. It also did the same at Makoul in Glen Spean, so that before the era of the lakes the western ice discharged itself over the very same cols over which the water flowed at a later period.

It has already been noticed that the era of the lakes was during the decay of the glacial period. When the thaw set in the thinner ice to the north east would disappear first. The col or watershed at the head of the Spey would become sufficiently open to admit of water passing out, and as soon as the ice melted out of the top of Glen Roy a lake would take its place, discharging itself over the col. Such a lake might, at first, be superficial—that is to say, resting on the surface of the decaying glacier. Gradually the ice melted farther and farther down Glen Roy and became reduced in height, but the surface of the lake, being determined by its outlet, would stand at the uppermost line until

the barrier melted back as far as Glen Glaster. That the glacier filled the valley above Glen Glaster is shown by the fact that the top road ends there. As soon as the water gained admission to this side glen it would escape over the col at its head, assuming it was unobstructed, and as that col is 80 feet below the one at the head of Glen Roy, the lake would sink to the level of the middle line in Glen Roy. There it stood until the ice which occupied the lower part of Glen Roy shrank back far enough to allow of the water communicating with Glen Spean. When this occurred the lake would spread into Glen Spean and drop to the level of the col at Makoul. The last to yield was that portion of the glacier which derived its nutrition from Ben Nevis and the mountains north and south of Loch Arkaig. At last, this also yielding, the waters in the glens would take the course they follow to-day.

It has been urged as an objection to the glacial theory that Glen Roy and the others to the east must be considered empty of ice, while glaciers of great magnitude occupied Glen Treig, the lower end of Glen Roy, and the valley of the Caledonian Canal. Looking merely at the comparative heights of the mountains this objection seems perfectly reasonable, but the paradox is solved when we consider the comparative rainfall already alluded to, which would fall as snow during the glacial epoch. Rain runs off as it falls from year to year, but with snow the case is very different. Take two adjoining districts where the snowfall is as two to one. Say that in the course of a year twenty measures of snow fall on A and only ten on B, and that the loss by evaporation and melting amounts to eight measures in each of them. The result is that on B two measures of snow remain for conversion into ice, and on A twelve; so that although the fall is only as two to one, the growth of ice will be as six to one. Let this process go on, not for one year, but for a thousand or many thousand years, and it is easy to see how the ice will grow upon the one and gain upon the other. Put A for the West Highlands and B for the East, and this will help to show how it came to pass that there was such an excess of ice on the former. The mass of ice lying over Argyllshire and the West Highlands, being immensely thick, must have of necessity lingered on for a very long time after the thinner ice to the north-west had melted away, and as this region of thick ice lay right across the mouth of the glens where the Lochaber lakes were situated, it explains in a consistent and reasonable manner that very remarkable circumstance which has appeared so inexplicable to Prestwich, Milne-Home, and many other observers. This also, in my opinion, answers an objection raised by Professor Bonney. He says, "The district about Glen Roy was not materially lower than the hill-region to the west, and

the rainfall, though less heavy than in it, was still considerable. To form large glaciers in the region of Ben Nevis would require a temperature at the coast not higher than 30 degrees (really this would hardly be low enough). If so, the temperature on the hills above Glen Roy would not rise above 26 degrees (annual). If, then, the cold sufficed to form glaciers large enough to choke Glen Roy or Glen Spean, there would be glaciers also in Glen Roy itself, and it would be filled with ice, not water." We must remember that the lakes were formed during the decay of the ice and not when it accumulated. We have seen that the mass of ice must have been enormously greater in the West than in the East, therefore it is quite within the bounds of probability to suppose that although the climate had become sufficiently mild to permit of a lake being formed in the upper part of the glen, yet the mass of ice at its mouth would take ages to melt away, seeing that it would be continually re-inforced during the colder months of the years, but in a gradually decreasing amount as the average annual temperature increased. Professor Nicol maintained to the last that the "roads" were sea-beaches, and urged that there are no well defined river channels or "notches" at the cols, such as he says would have been cut by the streams flowing out of the supposed lakes. These cols, we must remember, are practically flat, with a falling gradient of only from 1 in 660 to 1 in 440, which is insufficient to have caused the stream issuing out of the lakes to cut a groove of any kind, so that the conditions necessary for the erosion of a well-marked channel are here wanting. A river passing over a wide flat surface tends to accumulate sediment rather than to cut into its bed. Moreover the places are now overgrown with peat which obscures any track that might have been left.

Although, no doubt, there are minor difficulties which still require fuller elucidation before the glacial theory can be accepted as complete and uncontrovertible, yet I think you will agree with me that there is more evidence of truth in it than in any other theory yet advanced, and, in the light of our present knowledge, than is ever likely to be propounded.

I will now give a brief description of my visit to the district. Being a somewhat enthusiastic cyclist I journeyed by road from Glasgow, arriving at the Roy Bridge Hotel one afternoon in August, about 3 o'clock. As it was too late in the day to attempt any serious work on the mountains, I took the opportunity to make a reconnaissance, selecting the Bohuntine Hill as the most likely place from which to obtain a good general view of the district. Crossing the bridge and following the river Roy, a first view is obtained of the "roads" at the mouth of Glen Glaster, but as the terraces are here rather indistinctly marked the first impression is

somewhat disappointing, and to a casual observer they would not be likely to attract any particular attention. Turning to the left and passing through the hamlet at the foot of the hill, I proceeded to ascend to the top, in doing which the route led across one of the shelves. Although when seen at a distance the terraces appear very distinct and apparently flat, yet as a matter of fact they are neither the one or the other. As a rule the angle of the surface does not vary very materially from that of the face of the hill on which it is formed, and often being covered with grass and bracken it is a matter of considerable difficulty to exactly locate the shelf when on the spot. They are seen with the greatest distinctness when viewed at the same level on the opposite side of the valley. Most writers express great difficulty in accounting for this marked contrast when seen close to and at a distance. To my mind the explanation appears simple. It is merely a question of the relative angles the surfaces present to the eye.

A splendid view of the Roads on both sides of Glen Roy repaid the trouble in climbing to the top of the hill, and I had a good opportunity of forming plans for the morrow; a ramble of about eight miles concluding the work for the afternoon. Next morning the start for a day's tramp over the mountains was made about half-past eight. The morning was bright and warm and I set off at a steady swing along the same road as taken the previous day, following it for about five miles. The ascent was commenced up the pass to the north of Leana Mhor. On reaching the level of the top shelf I set my pocket aneroid at 1,150 feet, the height of that road above the sea level. The summit of the pass was shown to be 1,680 feet, and a specimen of the rock was obtained. Skirting the steep sides of the hills on my right, which necessitated considerable scrambling across the gullies, I reached the corner of Glen Gluoy where the terrace is first unmistakably detected at a level of 1165 feet. I then followed the course of the shelf up the glen as closely as practicable, but although it was so plainly indicated on the opposite side of the glen I found it no easy task to keep on the right track. Walking on the side of a hill for many miles at a stretch, at an angle of about 45 degrees, is considerably trying to the ankles. Those innocent little lines seen on the map indicating streams crossing the path mean so much extra work and often quite a little scramble in crossing them.

For some two or three miles along the west side of the glen I observed what appeared to be another terrace about 200 feet below the regular one, but though it is not marked on the Ordnance Survey Map I learn on the authority of Mr. Wm. Jolly that another "road" exists at the height of 964 feet. About two o'clock the col at the head of the glen was reached, and as I had kept up a steady tramp since starting at half-past eight I

concluded it was about lunch time. Halting by the side of a stream of water I appeased the cravings of the inner man with biscuits, chocolate, and lime-juice mixed with water from the brook at my feet. I find the latter a most agreeable and refreshing drink when undertaking protracted bodily exercise.

The col was found to be fairly flat, covered with a considerable thickness of peat, and, as near as the eye could detect, at the same level as the Glen Gluoy shelf. In the course of an hour I resumed my walk and leaving Glen Turret on the left turned down Glen Roy. The thick bed of peat met with at the col continues down the lateral valley until it joins Glen Roy, and as it is very much broken up and washed away it is impossible to detect any traces of the terraces in the upper part of the valley, although the lake would have filled it much further than the terraces can be traced. My attention was particularly attracted by a large mass of detritus at the junction of the Turret with the river Roy. This accumulation has been subsequently cut through by the water revealing a fairly regular stratification of the whole. The most remarkable accumulation, however, is lower down the valley near the mouth of Glen Glaster. Mr. Jamieson remarks of it as follows:—" Where these two upper lines cease Glen Roy is very narrow, and at this part of it there is a remarkable accumulation of detritus which commences rather suddenly just near the Gap at the hill of Bohuntine. It is thickest near the Gap, the quantity between that and the mouth of Glen Glaster being greater than it is further down the valley. This stuff consists of sand, muddy gravel, and silt with a few stones, but there is rather an absence of large boulders. Much of it is well stratified and some of it even finely laminated. Both its nature and the stratified mode of its arrangement show that it has been deposited in water. Now, where did all this stuff come from, and how did it lodge so thickly just here, right opposite the north end of Bohuntine where the two upper lines stop? There are no streams joining the glen between the Gap and Glen Glaster to have brought it in, and that is just the place where it is thickest. Above the Gap Glen Roy is comparatively empty of detritus until we come to the junction of the Turrett. My notion is that this mass of detritus consists of the gravel and mud that fell into the lake from the front of the glacier, when it stood across the mouth of Glen Roy during the time of the two upper lines. Here it made a pause and that accounts for the presence of such a heap of debris at that particular spot, for the laminated character of part of the materials, and also for the rudely stratified arrangement of the whole. It appears to have filled all the bottom of the glen, reaching near the Gap almost up to the line of the lowest road, but has been cut through afterwards by the retiring water. This mass of debris

attracted the attention of MacCulloch and other observers; it is particularly noticed also by Prestwich, but so far as I am aware no one has given the foregoing explanation of it. Its existence seems to me to form a most interesting link in the chain of evidence for the glacial theory of the lakes, for it is in complete harmony with that theory and no other."

I arrived at the hotel at 7 o'clock, ready for a substantial dinner and feeling considerably easier when my heavy boots were removed. The distance covered as measured on the map was about 25 miles, but the actual ground traversed was considerably more than that owing to the unavoidable deviations. Next morning the weather was what the Scotchman calls "soft," but my time being limited I had to make the best of it. To save time I availed myself of the bicycle and rode in the direction of the Rough Burn up the Spean Valley, my object being to examine the remarkable evidences of glacial action to be seen in that neighbourhood. Leaving the machine at a cottage about four miles from Roy Bridge, I walked on for another mile examining the surface of the rock where exposed, which showed distinctive evidence of glacial erosion. The faces are very flat and smooth, having a southerly dip, indicating that the glaciers came from Glen Treig and the neighbouring valleys. The hill sides are strewn with huge granite boulders; the specimen on the table was chipped off a boulder on the top of a hill some 800 feet above the river. A "soft" morning in Scotland is not conducive to a dry skin, and by the time I had secured the specimen I was completely wet through. Under the circumstances I did not carry out my intention of climbing to the top of Craig Dhubh, 2,161 feet, to see the boulders which may be met with even at that height. The district round here is extremely interesting from the prolific evidences of glacial action and is worthy of careful study. About noon the hotel was once more reached and a much needed change of clothing donned. Packing up my traps in the afternoon I set off eastwards continuing along Loch Laggan and over the col at Makoul. Although this is undoubtedly the col which determined the level of the lowest shelf in Glen Roy, there are now few traces of the shelf visible in the upper part of Glen Spean.

It was with extreme regret I turned my back on this interesting locality, and I hope it will not be long before I have the pleasure of renewing its acquaintance.

Mr. Cuttriss had prepared a plaster model of the district round Glen Roy to illustrate his paper. By its aid he was able in an admirable manner to show how the level of the lakes would be determined by the retreating glaciers and the cols at the various epochs.

Mr. John Redmayne followed with an outline narrative of

"A TOUR ROUND THE WORLD."

The route taken by Mr. Redmayne was by the Mediterranean and the Suez Canal to Ceylon, and thence to Australia where visits were paid to Adelaide, Melbourne, and Sydney. New Zealand then received a visit and the return journey was made to San Fransisco, and thence across the North American Continent home. The lecturer gave a rapid survey or a bird's eye view of the various places seen *en route*, and added many interesting details of the social, political, and commercial conditions of the countries visited. His address was illustrated by books of photographs and also by numerous curios, including corals, jade knives, kauri gum, and articles of native dress and ornaments. Hearty votes of thanks were passed to the lecturers.

Time not permitting the conclusion of the Holiday Notes, an extra meeting was arranged on Feb. 9th for that purpose.

JANUARY 19TH, 1893.

Mr. JOHN INGLEBY, President, in the Chair.

"THE GENERAL GEOLOGY OF SCOTLAND," BY Mr. DAVID FORSYTH, M.A., D.Sc.

I. THE GENERAL PHYSICAL CHARACTER OF SCOTLAND.

The northern portion of the island of Britain is physically connected with the larger southern portion, and yet presents many points of divergence from it in physical structure and in natural features. To the intelligent stranger approaching the country from the south there is no marked barrier separating the one country from the other; the Tweed might be (as far as appearance goes) the stream of an English county, and the Esk no longer rolls blood-stained waters to the Solway to mark the bitter hostility of nation against kindred nation. Yet to the observant stranger there is a difference; the undulating lines of the land receding from the eye might be English, but the background, everywhere bounding the horizon in Scotland, and everywhere forming a pronounced feature in the Scottish landscape, has for him a new and a refreshing attraction in contrast with the monotonous flatness of Central and Southern England. And nearer acquaintance proves these hills to be no pigmies, but outliers of real mountain-land,

> 'Mountains that like giants stand
> To sentinel enchanted land,'

while a keener air, a sterner aspect, a broader speech, make him

aware that he is "o'er the border." He has entered no mere province of England, but another English-speaking land. The great proportion of the people are English by descent, as English as the people of Yorkshire, but the national development bred a literature of its own, and *that* made it not a dialect but a language. This northern English (and in so speaking I include the English of Yorkshire), is *purer English,* because further removed from continental influence; the language contains more old English, and more words of force and meaning than the speech of Southern England. The speech of Northern England and Scotland is more nearly the language of Spenser and Shakespeare than is the tongue of London.

The mountain system has imparted to Scotland a prominent physical feature, and its arrangement into three main lines of elevation has marked off the country into three great divisions—the Northern Highlands, north-west of Glenmore and the Caledonian Canal; the Middle or Central Highlands, north of the Lowland Plain; and the Southern Highlands, to the south of the same plain. The small size of the country, and the nearness of the ridges (principal and secondary), allow of the formation of only small plains—the central plain and the plain round the head of the Solway being the chief examples. Small as these plains are, they are the scenes of the great agricultural, industrial, and commercial activities of the country, and in these pursuits there is no want of that Anglo-Saxon energy which makes Ayrshire and Lothian farming rival that of the richest lands of England, and which makes Glasgow rival Liverpool.

In looking at the map of Scotland one is struck with the remarkable difference between the characters of the West and East Coasts. The fringe, or sometimes the double fringe, of islands that guards the country, like mighty breakwaters, from the force of the Atlantic waves, is a prominent feature on the West Coast; and its absence is as remarkable on the East Coast. And nearer acquaintance only increases the differences. The deep firths that run so far into the land, with their endless variety of form and scenery, and the towering cliffs of the West Coast, are in contrast with the less numerous but larger firths on the East, and the general lower elevation of the surface. And yet these lonely Highland lochs serve an indirect and secondary, but very useful purpose in the commercial interests of the country. The tidal waves are dissipated among them, and the tide at the Broomilaw of Glasgow does not interfere with the discharge of vessels at the river quays at all times. Docks have been formed for the increase of accommodation for the ever-increasing traffic, but not from the natural necessity of the difference of tides, as at Bristol and Liverpool.

As the arrangement into three divisions simplifies our conception of the mountain system of Scotland, so the rivers may be grouped in an equally simple way. Each of the great ridges is a watershed, with two slopes, and two river systems running mainly at right angles to the mountain chains. (1). From the Northern Highlands numerous mountain streams run tumbling to the sea towards the north west, and somewhat longer ones to the south east, well known only to the geologist or the fisher. (2). From the Central Highlands run two sets of streams, but as the sea does not now fill the channel of Glenmore, or the low land between the Firths of Forth and Clyde, the streams are deflected towards the sea eastwards and westwards. (3). From the Southern Highlands the rivers run according to the same general rule N.W. and N.E. and S.W. and S.E. Yet to most rules there are exceptions, and to this rule there are exceptional rivers, the Spey and the Findhorn in the Northern Highlands, the Stinchar and the App in the Southern Highlands run parallel to the main chains. And the Tay, parallel at first to its parent chain, whenever it gets out of the mountain grasp, follows the general rule. The Girvan on the other hand begins its course according to the rule, but is caught in a fold of the Silurian strata and ends as a stream running parallel to the mountains whence it sprung.

Such are a few general hints as to the general physical configuration of the country. The details will be more readily grasped in the second part of the lecture where I deal with the general geology of Scotland, for in no country is the great principle more ready of application that geology and geological principles should form the only real groundwork of physical geography.

II. The General Geological Structure of Scotland.

A.—Archæan and Cambrian.

In the extreme north-west of the country are a series of rocks which as they lie below the oldest fossiliferous rocks, have been styled Archæan. They consist of crystalline gneisses and schists, and from physical considerations Murchison termed them the Fundamental Gneiss, and considered them as representatives of the Laurentian system of Canada. In sailing up the west coast there are manifested many sections where crumpling and twisting indicate possibly that the strata lie in many folds, and that constant plications give them an apparent thickness they do not possess. As however there are no fossiliferous beds, it is impossible to make out the succession or the repetition of the parts of the series. Sometimes thin patches of limestone are met with but these are so crystalline that no evidence of fossils has

been discovered in them, and the occurence of such beds is so irregular, that they do not aid in settling the succession of the rest. The massive gneiss is characteristic of all the parts of the series; but in the extreme north west it becomes pinkish in colour from the presence of orthoclase felspar and pegmatite in veins. The pegmatite veins in many cases lie along the plane of the stratification of the gneiss, and coincide with its foliations, as if therefore it had been included in the gneiss before its foliation. At others places the veins of pegmatite cross the plane of stratification at all angles. At other parts of the district hornblende schist is common as at Gairloch, while at Loch Inver an unctuous chloritic schist is common. This part of Scotland is one of the bleakest and barest in the British Islands. Not a tree, or even a bush is to be seen for miles, and even the sturdy heather finds but a bare subsistence, while whole hill masses are without a tinge of green. Even to an ordinary observer this terrible bareness marks off the old gneiss from the other formations of the district. The endless twinings and turnings of valleys, and the dome-like shape of the hills point to an excessive denudation. From the high level of the ridge between Gairloch and Poolewe the flowing outlines of the mountains, all much of the same level, the hard hummocky hills, the numerous small lakes or tarns, the deeply gouged-out valleys, and the ground-down surfaces are outstanding proofs of severe glacial action, just as the endless network of firths and bays with their accompanying archipelagoes tell the same tale. A wondrous land of sameness of outline and variety of scenery! In fine weather a fairyland of narrow waterways, precipitous cliffs, and pyramidal mountains! in bad weather, enveloped in fog, incessant drizzle, or terrific downpour, it is a terror to captains, and, a something never to be forgotten by passengers.

In passing let me say a word in favour of the weekly sails organised by McBrayne and Co. in the "Claymore" and "Clansman." The constant change of scenery, the invigorating air, the alternate turmoil and quietness of the seas, the wholesome fare, and the unconventional happy crowd of passengers, render a week as happy and as health-giving and as restful as ever I spent.

Cambrian.

Above these ancient rocks lie unconformably, in nearly horizontal layers, or as gently inclined strata, a series of reddish-brown sandstones and conglomerates. These have been regarded as Cambrian, or at any rate as equivalent to Cambrian, but as no fossils have been found in them their exact geological origin is yet a matter of uncertainty. They certainly underlie strata which the recent researches of Mr. Peach have proved to be Lower

Silurian, and they differ so much in character from either the underlying Gneiss or the overlying Silurian, that they must be either Cambrian or Huronian. Instead of the mounds and gigantic swells of the ancient Gneiss there are terraced-mountain sides, due to difference in weathering, and towering summits, almost cone-like, evidences of the excessive denudation of their original plateau-surface. The richer vegetation of the base is in contrast, too, with the lone barrenness of the upper steep summits. One pauses in presence of such old land surfaces and thinks, if the old Archæan Gneiss shows a denuded surface and upturned edges upon which rest, almost horizontally, mountains 3,000 feet high, what time must we accord to the growth of such a small portion of Scotland ?

This district, or rather a small part of it, to the West of Loch Eriboll and the Kyle of Tongue has been a veritable geological battleground. Professor Nicol, of Aberdeen, contended that the schists to the eastward were only the older schists and gneiss brought to the surface by great displacements, and exposed by denudation. Murchison declared that the schists and gneisses to the eastward were quite different from the old Archæan Gneiss. The discovery of Lower Silurian fossils in the Durness Limestone still further complicated the debate, and the battle rose high. Professor Lapworth, having examined the printed work dispassionately of both sides, quietly went to the district, lived in shepherds' huts and gamekeepers' boothies on the roughest fare, and solved the difficulty. Professor Nicol was right—the old gneiss had come up from beneath thousands of feet of superincumbent strata, and had been thrust sometimes ten miles *along* and *over* the surface of the strata *overlying it geologically*. What dislocations, what upthrust and lateral thrust have occurred in this old land surface! And what changes of rocks—*sandstones* into *gneisses* and *quartzites*, and flags into *micaschists*, until the whole land seems turned upside down!

B. Silurian.

The Silurian system is much more fully developed in Scotland and occupies two quite distinct areas—a Northern and a Southern. The Northern Silurian area is the more extensive and occupies a zone between two lines—one from the Mull of Cantyre to Aberdeen, the other from southern Skye to Loch Eriboll. The rocks are mainly crystalline—gneiss, mica schist, chloritic schist, quartz rock, &c., and for a time their geological origin was unsettled. But the discovery of Lower Silurian fossils at the base of this enormous mass of crystalline rocks has caused geologists now to accept the decision, that the area is composed of metamorphosed Silurian Strata. The evident contortions, and possibly

many more not seen, and the presence of the granitic axis stretching from S.W. to N.E. almost continuously from Mull to Aberdeen, sufficiently account for the extraordinary amount of change the beds have undergone. More diligent search among the old limestones of Argyllshire and Perthshire may make the evidence more conclusive. The Silurian area of Southern Scotland is much more interesting, but as I had an opportunity last year of addressing you on the geology of one part of it, and I hope to have the same opportunity on other parts, I shall speak only briefly of this most important district. It stretches as a broad belt from one side of the Lowlands to the other, bounded on the North side by a line from Girvan to Dunbar, and on the South by another from Kirkcudbright to Berwick. In the Girvan district the strata are remarkably fossiliferous, with Landovery and Bala beds well developed; in the Central areas graptolitic beds, and now radiolarian cherts, give a key to the patient investigator as to the relations of beds; in the Eastern among the Pentland Hills Llandeilo and Caradoc fossils determine the origin, and also along the edge of the Southern area in Kirkcudbright, Dumfries, and Roxburgh. Metamorphic action has not been so severe as in the Highland area, although there is plenty of evidence of it, and, what makes it very interesting, gradated evidence of its action in all stages, from simple hardening to complete fusion and molecular reconstruction. The South Ayrshire district has been to Scottish geologists what your Wenlock and Ludlow areas have been to English geologists, in the variety and finely preserved character of the fossil remains. Mulloch Hill, Penwhapple Burn, Craighead, Tramitchell, Aldons, are as fruitful fields to the collector as the jumbled serpentines, diallages, diorites, gabbros, and felstones in the south of the same district are his constant source of perplexity. I have worked at and mapped them for ten years and I am not sure that I have made out the correct relations even yet. If I could just transport you by the magician's aid to this noted district, I could in a week give you a better lesson in Silurian remains, and what *remains* to be done in Scotch Silurian rocks, than a year's lecturing would do. Its trilobites, its corals, its graptolites, its shell beds, are the sweet rewards; as the metamorphic series are the inciting puzzles. While the drive along the shore with its overhanging cliffs on the one side, and the sea on the other, with Ailsa Craig standing out as a protest against its ravages, and the Mull of Cantyre and Ireland like distant breakwaters preserving us—all but a narrow gap less than 20 miles broad—from the fierce Atlantic waves; and the smiling valley of the Stinchar with its glacial sections and clean villages, form a feast for mind and soul—one of those sunny memories which keeps warm the geological heart during the dark wintry

round of duty and work.

C. Old Red Sandstone.

From the Old Red Sandstone of Scotland two important lessons can be derived. Firstly, it shows everywhere a division into Upper and Lower, both by unconformity and by difference in fossils. Secondly, it occurs in distinct basins, pointing to deposits in great inland lakes. Of these there are at least three or four distinct basins, the northern extending from the Shetland and and Orkney Islands, through Caithness and Cromarty, to Inverness, dipping away towards the German Ocean, and possibly connected with the Old Red of Scandinavia: the great central fringe skirting the Coal Measures both towards the north and the south and stretching from sea to sea: a minor area of deposit round Oban: and another small one forming part of the Cheviot district. In all these areas fossils are well distributed, but in many parts, as the deposits occupy lonely upland districts, where little quarrying or mining is carried on, one has to trust to natural sections; and many a place found barren may produce unexpectedly new forms. Nor is this area without its contrasts. In the Lesmahagow district, the high ground between Ayrshire and Lanarkshire, a small anticline yields many remains distinctly Silurian. And among them are Pterygotus, Slimonia, Eurypterus; and the same remains are found near Arbroath among strata distinctly Old Red Sandstone. Again in the Lesmahagow district there is no uncomformability between Silurian and Old Red Sandstone. In Old Red localities there is distinct unconformability. My enthusiastic geological friend Dr. Hunter adopted the right method with this district—he pitched a tent among the hills, and employed workmen to blast for him, with the practical result that instead of forms 10 to 12 inches long, he unearthed Pterygoti nearly three feet long. Another remarkable feature of this formation is the occurence of prodigious masses of interbedded volcanic rocks. The Sidlaws and Ochils are largely composed of these old lavas, interstratified with ordinary sedimentary flags and sandstones. The fish remains of Dura Den are historic, and the huge slabs still kept in the office of the mill in the quiet Fifeshire village are worth a pilgrimage itself; while the beautiful pebbly beaches and wondrous caves between Arbroath and Auchmithie are lessons themselves in the denuding power of the sea, especially when the rocks in weathering and wearing yield an artillery to be used against themselves.

D. Carboniferous.

To geologists who are intimately acquainted with an English coalfield I need not dwell on the special features of the Carboniferous formation, but rather point out the differences which

characterise the Scottish Carboniferous area from those further south. There are three very distinct features to be noticed in the Scottish Carboniferous system—(1) The evidence of extraordinary volcanic activity—in the lowest or earliest part of the formation—where the volcanic outbursts were so great as to leave still in evidence such chains of hills as the Campsie Fells, the Kilpatrick Hills, and the Ayrshire Heights, marking in fact the rims of the various coal basins of the country; (2) the absence of the Millstone Grit, or its representation by only a few thin beds of sandstone, thickest perhaps near Glasgow at Giffnock and Bishopbriggs; (3) the comparatively trifling nature of the Carboniferous Limestone. In comparison with your magnificent Pennine limestone the thin sandstones, shales, coals, clays are insignificant, for even the most famous of our limestone beds near Beith in N. Ayrshire are only 100 feet thick, and they form the most massive limestone formation in the country. Of course the presence of fireclays and coalseams gives this part of the system an economic value of great importance. Many of our early coal-pits and ironworks were established near these lower coals, whose uptilted edges against the lower volcanic ridges first attracted the attention of the industrial population. The zone of Coal Measures (strictly confined between the two lines from the mouth of the Clyde to the mouth of the Eden, from the Girvan to the mouth of the Tyne in Haddington) marks the industrial zone of Scotland. Outside this area there are few large towns, Dundee and Aberdeen being the only exceptions.

E. Permian, Trias, Lias, Miocene.

Thus far the geological formation of Scotland was finished: or in other words Scotland was finished when much of England was yet to make. A glance at the geological maps of the two countries will show what I mean. All the extensive deposits to the S.E. of a line from the mouth of the Tees to the Dorsetshire coast are only represented in Scotland by a few patches. The Permian is represented only by patches of red sandstones and breccias in Dumfries and Ayrshire.

The Triassic rocks are represented by some sandstones in Elgin: The Lias and Oolite are restricted to the Inner Hebrides and to the east coast of Sutherland. The volcanic plateau, or parts of it, seems to have covered up the Lias and Oolite of Western Scotland, and denudation has laid bare the underlying rocks. No more interesting picture to the tourist can be mentioned, then the contrast between the brown, red, and black of the lavas and basalts overlying the yellow and grey Oolites, and the contrast between the unfossiliferous volcanic covering and the wealth of remains found in the under-

lying strata is marvellous. At Broadford, in Skye, the limestone is burned. At Pabba, Gryphæa, Lima, Astræa, are as abundant a in your own Yorkshire. The sea has hollowed numerous caves, and I remember spending a forenoon in one near the head of Portree where the roof was basalt and the sides Jurassic, studded with Astræa, Gryphæa, and Belemnites, while the cliffs to the north of Portree are rivals to your own Flamborough, in geological interest and in fossil remains. In Mull, near Tobermory, I have found a few Ammonites in fair condition, but nothing of the size, nor yet of the variety of the forms found in Yorkshire. If any one has visited the north of Ireland he must remember the same structure, a superincumbent plateau of volcanic material, covering up the underlying Chalk and Lias.

Cretaceous:—Real Chalk rocks are only found in the same position, underlying the volcanic rocks of Mull and Morven: unless we take as indirect evidence the presence of chalk nodules in Aberdeenshire as a hint that Chalk may have overlain that district and have been denuded.

Miocene:—The great Tertiary plateaux play a much more important part in the geology of the West Highlands. Not only do these cover large tracts of Mull, Skye, and the intervening islands, but many outlying spots indicate that these volcanic sheets extended much more widely. There is evidence in the very wrecks of this much denuded sheet, that a large area must have been covered with volcanic material for more than 3,000 ft., and Prof. Judd calculates that the central volcanic cone of Mull may have been not less than 10,000 ft. high. The dykes which traverse the country, crossing older and newer formations in unswerving lines eastwards, north eastwards, and south eastwards, evidence a great rending force, by which fissures many miles in extent were opened and then filled with basalt, pitchstone, dolerite; and we have clear proofs that this last effort of volcanic activity in Scotland, took place before the present detailed configuration had been given to the country. The Island of Eigg is one of the most remarkable features of the district, and of astonishing geological interest.

F. Glacial Age and Post Glacial Deposits.

Geologically, the structure of Scotland was now complete; but everywhere the country bears evidence of intense glaciation. The boulder clay that flanks the hills and covers the valleys, the erratics that strew the land and fringe the coast, the rounded outlines of the hills, and the striated surface of the rocks, all indicate long-continued ice-action. While the "scaurs" that disfigure many of the river banks rudely measure the thickness of the glacial clays, as most of the river channels have been scooped

out of the boulder clay. The post-glacial stratified clays that mark so many of the sheltered bays of the coast teem with Arctic shells, and their terraced arrangement seems to indicate various changes of level. After these "Auld Scotland" was left to the combined agencies of denudation that are ceaselessly but imperceptibly altering the conformation of all lands. From its northern latitude, from its greater elevation, and from its longer existence as a land area, glacial action has been more severe there than in any other part of the British Islands. Notwithstanding the effects of denudation, *glacial striæ* are still readily seen, and in almost any district the removal of the turf reveals the old "scorings." On the steep sides of the Campsie Fells, on the shores of nearly all the lochs, and the ridges of the low "whale-backed" islands, striæ can be traced. The general contour of many of the hills—all being variations of the long outlines of a rounded curve—points to the effects of a general ice-cap, which moulded the general outline of the country, and especially of the higher and harder hills. And notice, too, the lakes on each side of the ridges—often salt water on one side and fresh on the other, but *glacial* both. Most of the Scottish lakes are in rock basins, deepest where the glacier, emerging from a narrow glen, plunged like an icy plough into the lowland country, and shallowest where the glacier, having expanded, moved forwards more horizontally. Every sea loch on the West Coast bears evidence in its soundings of the same action, and its spit of shallower water shows where the glacier was losing its ploughing power, before it joined the sea. "Boulders"—or masses of rock not native to the position in which they now stand—tell of the same mighty moving force. The tiny rivulet that murmurs as it vainly attempts to dislodge the stranger blocking its way, the huge granite blocks that line the Ayrshire Coast where no granite is (the lintels and doorposts of the houses, and the gateposts of the farmyard are all granite there), the mighty Baron's stone (weighing about 40 tons), where, tradition tells us, the barons of Killochan dealt out short mediæval justice to their retainers, all come from the granite mountains around Loch Doon, nearly 30 miles away. In excavations made for the foundation of the University, Mr. Young, of the Hunterian Museum, made a collection of the rocks found in the boulder clay, and a large proportion of them were genuine "Highlandmen." The Ayrshire plain was the battle field of two iceflows, one from the north and one from the south. In a deep section on the banks of the Douglas Water I distinctly remember, in my boyish geological rambles, being puzzled by *mica schist* and gneiss which I had never seen in the district *in situ*, nor yet have seen. For over the southern barrier no "Highlandman," so far as I have ever observed, has come. No mica schist, no gneiss, is found in

Galloway. The southern iceflow was weaker, but in its last line of defence—at its own doors—it beat back the intruder.

From observation of the division of the striæ, and from the noting of the mineral character of the boulders, geologists have been able to construct a map of the *glaciation lines* of the country. You see from it how glaciers moved eastwards and westwards from the N. Highlands, and S.E. and S.W. from the Central Highlands, and mainly southwards from the S. Highlands.

The tough "till," a boulder clay, everywhere marks large tracts of country, high up the hillsides even, but thicker in the valleys, unless where denudation has removed it in whole or in part. Evidenced in deep scaurs in many of our glens, it forms a marked feature in the physical structure of the country.

In many glens moraines can still be traced, damming back small lakes, or after having been "breached" by the river, still exhibiting the mounds in each bank. Perched blocks, that stand on points, and although tons in weight, can be moved by a single man, and "roches moutonnees," are also remains of the *Great Ice Age.*

The "parallel roads of Glen Roy" are classic, and the kames of Carstairs are textbook illustrations.

Although I do not mean, in a *general* lecture, to point out details, yet I cannot pass from this interesting geological age without saying that I have not been able to make the distinction between upper and lower boulder clay, which is insisted on in the "Great Ice Age" of Prof. Geikie. But to these details I hope in some future paper, devoted more specially to a bit of Scottish geology, to refer more fully.

Such then is a brief summary of the *General Geology of Scotland,* and in order practically to summarise the results, I have made a rough section from Cape Wrath to the Solway, leaving out details, so that you may readily understand the general lie of the country, or, in other words, I might draw a parallel between it and your own country.

In the Ingleton district you have a representative of the older rocks of Scotland. Your Pennine Chain and coalfield represent the Scottish Carboniferous; while eastwards you have in full development those formations Permian, Triassic, Jurassic, Cretaceous, which in Scotland are represented by shreds and patches. If Scotch geologists feel a little pride in their antiquity of formation, you are of the modern type and *up to date.*

III. Influence on the People.

From such differences in physical conditions, and all their attendant consequences, it is natural for us to expect similar differences in the inhabitants. A glance at the map makes us

think of the *mountaineer* and the *lowlander*—not in the ordinary sense of the terms—but the *mountaineer* by nature a herdsman, a hunter, a warrior, a freebooter; the *lowlander* an agriculturist, a tradesman, a mechanic. The Highland forays of past times were the natural outcome of such a condition of things. They were not robberies, but the natural occupations of Highland gentlemen, who looked down from their mountain fastnesses on the lowlands as their natural hunting-ground—especially after harvest. This difference of *mountaineer* and *lowlander* was still further accented by the difference in race, the great mountain-land being inhabited by a Celtic population, the southern district by an Anglo-Saxon. The antagonism in language and thought, in manners and customs, and in occupation, produced a divergence of feeling that often resulted in estrangement and misunderstanding, and an invasion of "the Highland host" was looked upon by the average lowlander as an invasion by a foreign and savage people. Nowadays the demand for labour, for thews and sinews in Scottish industries, has produced a better feeling between the two races, an invasion of peace and industry. And welcome to the great cities are the strong men of the mountains.

The Celtic races, coming originally from Ireland to a country abandoned by their kindred, the Picts and Caledonians, brought with them many Celtic characteristics—the natural impetuosity which has turned many a defeat into victory, and the loyalty even to a desperate cause. But the stern conflict with nature has altered the Highlander; it has taken from him that humourous side so characteristic of the Irishman. The imaginative power still remains, but it has taken a sadder, more solemn view of life, and the Highlander has become a grave, a dignified, a less joyous man. His poetry is either highly imaginative as in Ossian, or simple lays of ordinary life, with a sad wail of melancholy running through them in undertones. Much light has been thrown on the life and character of the early inhabitants of Scotland by the discovery of cave remains and of lake dwellings. Our forefathers were evidently hunters, for the bones of the deer and the wild ox are found among the debris; but grain also formed part of their food, and sometimes they must have been in straits, for quantities of shells, beech nuts, and acorns, show that the sea-shore and the woods had to help them in subsisting. The very nature of the lake dwellings—found also in Switzerland—seems to betoken a timid and ill-armed race, who built their huts on piles placed among the lakes so common in the land, just as the natives of the Amazon district do at the present day. And yet in an Ayrshire lake dwelling I have seen a bowl of Greek ware. The abundant flint remains—found in immense quantities at the head of Luce Bay—show the character of the weapons and point also to an

early traffic with Ireland, for no flint is found in Scotland worth mentioning. The sun and moon markings and stone circles indicate roughly the nature of their religion.

The stern struggle with an inclement climate and a poor soil have made the race indomitably persevering. The ever-present boulder-clay which covers most of Scotland was a stern national lesson. The Scotch farmer might speak of it as "the land that greets a' winter and girns a' summer," but he sets himself all the same to conquer it. And I wonder in these days of statistics that some one has not taken to calculating *the millions of tons* of boulders extracted from the cultivated fields of Scotland, or buried beneath their soil by hard manual labour. It would make a startling total of popular labour, that would go far to establish a popular right to the national soil itself.

There is a quaint belief present among the "Geological Survey Men" that on the flat lands of Caithness one sees one's friend at such a distance that the smile of recognition becomes so set before friends meet, that the features of the Caithness men have acquired a kind of broad grin. And I do not think any land has produced *naturally* so many eminent geologists, nor do I think many lands can show as many ordinary men of every occupation taking a delight in the subject. *Hugh Miller* and *Dick* are only types of many less distinguished, but as earnest men working to-day in many parts of the country. More pith to their hammers and to the sturdy limbs which lead over our rocky soil is, I am sure, our brotherly wish!

The hard circumstances of natural life bred in the people a self-reliance and a thoughtfulness that still marks the ordinary peasantry. The Scotch shepherd is a thoughtful, observant, reading man, who has strong political opinions, and knows *all the points of a sermon.* And the nation early recognising that in the battle of life it is not only strength of arm, but strength of mind that conquers, early recognised the need and the benefit of education only—not education of the few, but the education of the whole people. More than aught else it is this appreciation of education which has enabled the nation to dredge its tiny streams, to build steamships to sail all seas, and to send strong men with well-trained minds to many lands.

A nation's environments have, perhaps, as much to do with its national development as home surroundings have on the individual man, the hard rock-reared men fit to conquer it; and if the surface acquaintance with the people has given you an impression of a stern granitic look, there is the warm volcanic heart beneath. And no geologist finds a more kindly welcome than in the land where nature compelled men to consider the soil, and to conquer it by knowledge.

What wonder is there that such a land should produce a natural poetic literature? and that this poetry should have exercised a wonderful influence on the formation of the national character?

"Though no broad river swept along
To claim perchance heroic song,
Though sighed not groves in summer gale
To prompt of lore a softer tale,
Yet was poetic impulse given
By the green hill and clear blue heaven."

What wonder that her sons

"Cherish the remembrance still
Of the bare mountain and the rill."

The face-to-face contact with nature made man nobler and purer, brought to his lips naturally the words of song, and reared in him a spirit of reverence. The inhabitants of a mountain-land are naturally imaginative and romantic, contemplative and religious.

I have endeavoured to make this a general sketch on broad lines, with the hope that on some future occasion I may be able to take up a part and do it in complete detail. Last year I had the privilege of showing the results of painstaking, detailed labour; to-night I have endeavoured to be broader, but not so deep. Still, to all geologists, the knowledge in either way is of value, as giving scope to those thoughts which carry them even to the foundation of things, and to the growth and development of earth itself, or of any part of it. Nature's page can be read by the ordinary eye, or by the microscope; *large* and *small* are but relative terms in its study, and the *mind is blest in both.*

Might I not, in conclusion, make not only a natural reference to Scotland, but a practical, individual application to geologists everywhere, of this thought from another mountain poet—one who loved your mountains well, and understood them, though not geologically—Wordsworth—

"Who in this spirit communes with the forms
Of nature, who with understanding heart
Doth know and love such objects as exhale
No morbid passions.

* * * * *

Whate'er he sees
Whate'er he feels of agency direct
Or indirect, shall tend to feed and nurse
His faculties, shall fix in calmer seats
Of moral strength, and raise to loftier heights
Of love divine, his intellectual soul."

FEBRUARY 9TH, 1893.

HOLIDAY NOTES.

Mr. JOHN INGLEBY, the President, in the Chair.

"THE COAST BETWEEN EASTBOURNE AND FOLKSTONE"

BY Mr. A. FARRAR, F.G.S.

In this paper I do not propose to do more than indicate such of the more marked geological features of the coast between Eastbourne and Folkstone as were noticed in the course of a superficial observation with no other guide than Woodward's "Geology of England."

Every one has heard of, if he has not seen, the "White Cliffs of Albion," which fringe the extreme south-east of Kent. They form the seaward termination of the Chalk of the North Downs. On the south side of these downs the cliffs end abruptly at Folkestone, and, turning inland, form a high escarpment—the southern boundary of the North Downs—which is continued westwards to Farnham and Petersfield, in Hants, then turning sharply eastwards forms the north boundary of the South Downs, and terminates on the coast at Beachy Head, close to Eastbourne. This escarpment encloses an oblong-shaped area averaging about eighty miles long by twenty-five wide, and so well defined is this boundary-line that when a general view is taken from some elevated point it suggests an ancient coast-line, as at one time it was believed to have been. The whole of the country thus circumscribed is known under the general term of the "Wealden area," including the Greensands and Gault underlying the Chalk, which, as seen from the escarpment, are outwardly undistinguishable from the rest of the area enclosed by the Chalk, but the term "Wealden" is applied geologically to the series of fresh-water beds which were deposited in the interval between the marine series of the Upper Oolitic and Lower Cretaceous epochs. They cover the greater part of the area. Of the fresh-water origin of these deposits the fossils leave no possible doubt, but whether they were deposited in a great estuary or in a lake is still a matter of speculation.

The "Wealden" Beds are subdivided into two portions, each with different physical features. The lower portion is the "Hastings Beds," which, owing to elevation as an anticlinal and subsequent denudation, is the highest in position, and forms the uplands in the central part of the area, while on each side we have the upper portion, called the "Weald Clay," which forms plains, including the Weald of Kent, that has given a name to the series.

On the outer side it is bounded by the Greensands, which in places form hilly ground, and, lastly, by the Chalk escarpment. Like the North and South Downs, the Hastings beds terminate on the coast in high cliffs in the neighbourhood of the town of that name, which on that account has given its name to the formation. Beachy Head and Folkstone Hill are thus seen to clearly define the limits of a stretch of coast constituting the seaward boundary of an equally well-defined area, and exhibiting in its middle part the finest section to be seen of the Wealden Beds proper.

Suppose, now, we approach Eastbourne by railway from London, we see on our right the Chalk escarpment, with the bold, bare, and rounded outline so characteristic of that rock when denuded. The town itself is mostly situated on the outcrop of the Upper Greensand and Lower Chalk at the base of the escarpment, and in ascending the latter we pass successively over the outcrops of the Middle and Upper Chalk to the summit of the well-known headland of Beachy Head, 600ft. high. These beds have been brought to the surface as a consequence of the Wealden anticlinal already alluded to. Descending, and turning along the coast eastwards beyond the town, we at once enter on an extensive shingle plain, which extends to Pevensey, four miles distant. This village, built on a low boss of, I think, Greensand, and celebrated as the landing-place of the Conqueror, was formerly close to the sea, but it is now about half a mile inland, and it is not at all improbable that the eminence on which the Roman castle stands was, at the time of the erection of the latter, washed by the waves; at any rate, the bay was then more serviceable as a haven than it now is. The shingle plain gradually narrows to high, loose banks extending for about four miles, and forming a natural dyke between the sea and the large tract of fenland called "Pevensey Level," which is actually below high-water mark. This "level" was doubtless at one time a bay, but is now, as are all the Sussex "levels," covered with rich alluvium. Low alluvial cliffs, resting on the flanks of the central Weald uplands, next follow, but call for no special remark. Just beyond Bexhill we come to a small "level," with its shingle bank, and then reach the first visible section of the Hastings Beds at the extreme end of St. Leonard's, the west suburb of Hastings. This series has four lithological divisions, called, beginning with the highest—(1) Tunbridge Wells Sand, (2) Wadhurst Clay, (3) Ashdown Sand, and (4) Fairlight Clays. These have a local east to west dip, so that at the point at which we have arrived the cliff is of Ashdown sand, which, however, farther on, owing to a fault not here visible, is succeeded by the Tunbridge Wells sand, but on the other side of the fault it reappears, and

there is no important break for five miles. There is scarcely any lithological difference between the two sandstones, the distinction being due to the interposition between them of the Wadhurst Clay.

Hastings Castle is built on a high cliff of Ashdown sand, and the town itself lies on either side in two valleys scooped out of the same stratum, which unite higher up. Ascending the East Cliff from the eastern valley, we enter on the loftiest part of this coast section, the cliffs averaging about 300 feet in height. Here they are of Ashdown sand, capped by Wadhurst clay, but within a short distance there is a deep, narrow valley, at the bottom of which the lowest bed of the series (the Fairlight clays) appear. It is so called from the next valley, where, owing to the rise in the dip, they are well exposed, and form the greater part of the cliffs thereabouts. Partly from this change, and partly from the alternation of clayey and sandy beds, the cliff ceases to be perpendicular, and at Fairlight we have an open glen of great beauty, and a famous resort. From the lighthouse, when it is clear enough, the Chalk escarpments at Eastbourne and Folkstone, 45 miles apart, are both visible.

A couple of miles farther on the cliff drops, and the grey clay suddenly gives place to a low perpendicular cliff of brown Ashdown sand. This change is due to a reversed fault—a good example of the kind, and clearly visible. Bearing in mind the east to west dip of the rocks here, the westerly direction of the hade makes it evident that it is by an upthrow that the older clay has been brought up against the newer sand. A short distance beyond this point, between six and seven miles from its west end, the cliff section comes to an abrupt end, at what is appropriately enough called "Cliff End," or, rather, here it leaves the shore and turns inland. This place is in many respects a good spot. Besides the reversed fault, it furnishes excellent examples of the different effects of marine and subærial denudation. The sandstone facing the sea being in a state of constant disintegration from the combined action of these two agents, is always fresh and brown, but let us turn round the corner inland, and what a contrast! The rock here is as grey and hoary as an old ruin, furrowed into horizontal lines and prominences—the result of weathering alone. It was itself formerly, and not so very remotely, exposed to the fury of the sea.

If this inland cliff be followed some distance we shall reach a headland, at the top of which, on a level plateau, is perched the ancient and forsaken town of Winchelsea. The history of the village is a curious illustration of the shifting character of this coast. Originally Winchelsea was situated on the "level" at the foot of the cliff with a harbour, but after frequent inundations it

was destroyed by the sea, and another town was built on the present site by Edward I. It prospered until the middle of the fifteenth century, when the sea quickly retreated, rendering the harbour useless, and now the village is over a mile from the shore. Three miles across the "level" on an outlier, rises the picturesque town of Rye, its red-tiled houses giving it a Continental aspect, and looking like nothing so much as a miniature Mont St. Michael. It, too, was once a seaport, and although there is still a channel for small vessels, the sea is 2½ miles off. There is probably no more unique pair of towns in the kingdom than Rye and Winchelsea, but we must not trespass on the province of our friends the antiquarians.

From Cliff End the coast, as already hinted, entirely changes, for another "level" here forms the beginning of the great tract of Romney Marsh—now pasture land. A long bank of shingle sweeps away south-east, as far as the eye can see, towards Dungeness. Romney Marsh marks the site of a former bay, and inland cliffs on the landward side indicate the old coast line.

My observation of the coast did not extend beyond Cliff End, and, in fact, it was hardly necessary, for the shore is level all round to Hythe. In approaching Folkestone by the railway one sees, but this time on the left, exactly the same thing as at Eastbourne, the south escarpment of the North Downs; but here the Lower Greensand is better developed, and is well seen in the cliffs between the Chalk escarpment and Hythe. The Gault is also seen cropping up from under the Chalk, its dark green-grey being well contrasted with the white of the other. This was all I could note, as my stay here was very brief.

I will conclude by referring to one or two points which are forcibly impressed on the mind by a consideration of the diversified physical features of the Wealden area, and more particularly of the hilly part in the centre, the section of which is exposed on the coast between St. Leonard's and Cliff End. One is the evidence of vast denudation which is everywhere visible, and the mode in which it has been effected has been much discussed. The North and South Downs are the remnants of what was once a continuous stratum of Chalk, which afterwards, when the Wealden anticlinal was formed, subsequent to the Eocene period, became a dome-shaped mass. All this was swept away, mainly by marine action, and a plain of marine denudation formed at some point above the present hill tops. The underlying Hastings beds, in their turn exposed, have been so deeply and irregularly furrowed that the country comprised appears like a rolling sea of low-swelling hills with flat alluvial valleys, representing main lines of drainage, winding in and out. Whatever may have been the case with the overlying Chalk, the present aspect of this part

of the Wealden area leaves scarcely any other impression than that it is the result of subaërial denudation of an intense kind, to which three factors have contributed—the softness of the porous sandstones, and the action of running water combined with the subaërial action of a moist, varying climate. In a perfectly dry atmosphere we should have a higher level with narrower and deeper valleys.

Another point is the "travelling" of the shingle eastwards along the south-east coast. This is due partly to the waves and partly to the set of the tides and currents, and the results greatly depend on these and the configuration of the coast. Hence, we have flat spits of shingle as at Pevensey, and on a greater scale at Dungeness, or high ridges forming banks, which not unfrequently turn back the natural drainage of the land. In front of the towns, or wherever it is desired to maintain the old shore line, this travelling is regulated by means of groynes, i.e., triangular partitions strongly framed with the apexes pointing seawards, which, by impounding the shingle on one side and sending the surplus over to the lee side, serve to keep it moving without accumulating anywhere. Romney Marsh, projecting as it does beyond the main coast line, is itself a great natural groyne, so that it is not surprising to learn that the shingle towards its southern extremity covers an area of a dozen square miles.

Mr. William Cheetham, F.G.S., followed with a graphic account of

"A TRIP ROUND SCOTLAND."

The writer alluded to the troubles of a voyager with much humour, and described many interesting bits of coast scenery, with remarks on their geology. Especial reference was made to the magnificent scenery of the coast around Skye, and a description of the well known basalt beds of Staffa was given. The cliffs at Cape Wrath are very fine, being 600 feet nearly perpendicular. The course was then shaped for Hoy, passing within speaking distance of the remarkable "Old Man," now on his last leg; eighty years ago he had two legs. He reminded the writer of the "Pulpit Rock" of the Lizard, which eighty years ago was joined to the mainland. So our land is slowly but surely being worn away at each end.

Mr. E. Hawkesworth then read his

"NOTES ON SOME WITHERNSEA SPECIMENS,"

which included Norwegian boulders and shells from the lacustrine deposits of that locality. This paper is printed among the records of our Field Excursions.

Hearty votes of thanks were awarded to the readers of the papers.

FEBRUARY 16TH, 1893.

"THE CAUSE OF THE ICE AGE,"

BY MR. PERCY F. KENDALL, F.G.S.

The subject with which I have to deal is a very large and technical one, involving the handling of a great mass of facts, and the examination of many conflicting theories which, with the short time at my disposal, will be a matter of some difficulty, but I will endeavour to steer a course between unintelligible technicalities on the one hand and mere generalities on the other. I shall have to make one rather large assumption at the outset, in regard to the way in which the phenomena which remain to tell us of the Ice Age were brought about. All are agreed that ice in some form has been the agent, but opinions differ as to the importance to be ascribed respectively to glacier-ice moving over the land, and to floating-ice acting during a period of submergence. I shall be compelled to assume, as on a previous occasion I have attempted to prove, that the latter agent has been practically inoperative, and that the whole of the phenomena, with a few small though significant exceptions, were due to the action of land ice.

The question to which I have to address myself is: What was the cause of the conditions of climate which produced so tremendous an accumulation of ice and snow in our latitude?

Many theories have been advanced, and they may be conveniently considered under two categories. 1. *Terrestrial,* including those which ascribe the severe conditions to alterations in the earth itself; and 2. *Cosmical,* which invoke causes dependent upon changes in the environment of the earth, as, for example, in the temperature of space, variations in the form of the earth's orbit, and the like. Taking these in order one may quickly eliminate a good many as failing to satisfy some primary condition.

Terrestrial. 1. The cold has been ascribed to the loss of the earth's internal heat by radiation into space, but this cause is now known to be entirely inadequate; the internal heat has been calculated to make a difference of no more than $\frac{1}{30}$ degree Fahrenheit to our climate; and furthermore, as the cooling is progressive the glacial conditions should be more severe now than ever. 2. A change in the earth's axis of rotation has been invoked. This does doubtless change, but the extent of the change is very strictly limited; and furthermore, the zones of climate were in past times disposed in the same relation to latitude as at present, and to the same pole. 3. A former greater amount of moisture has been supposed, but no evidence has been adduced in support of such a hypothesis, and the facts of geology are against it. The

great salt deposits of the Silurian, Permian, and Triassic times—as has been well pointed out—are facts difficult to reconcile with this theory. 4. Sir Charles Lyell placed his chief reliance upon differences in the distribution of land and water. He considered that by massing the land areas around the pole, and leaving the equatorial regions entirely, or almost entirely, occupied by the sea, the climate of high latitudes would be rendered very severe. Such a disposition of land and water would have the further effect of depriving our shores of the Gulf Stream, which is at the present time such an important factor in the amelioration of our climate. The objections to this theory are multifold. All observations tend to show that the land area in high latitudes was not much greater during the glacial period than at present, and, undoubtedly, the increase of the area occupied by sea within the Tropics, other considerations apart, would *raise*, and not lower the general temperature of the earth. If we take account of the effect of a severance of the Isthmus of Panama, which is not improbable, or even may be said to be probable, we shall see that by diverting the Gulf Stream through into the Pacific Ocean a great agent in the production of that mild climate which we at present enjoy would be withdrawn; but those who rely upon this overlook the fact brought to light in recent years that fully one half of the Gulf Stream joins outside the Straits of Florida, and would not, therefore, be affected by any change in the geography of Nicaragua. There is another fact to which Lyell did not give due attention, viz:—That the glacial epoch has left traces in North America and Asia, as well as in Europe, and, not only so, but in the Southern Hemisphere—in New Zealand, Australia, and South America—it evidences remain, though not so manifest as in the Northern Hemisphere. That the glaciation of Britain, if dependent upon geographical causes, should have been synchronous with that of North America would have been a strange coincidence, but that such causes should have produced a practically world-wide glacial epoch passes credence. 5. General and wide-spread earth movements, producing great continental elevations, have been adduced as a cause by a number of American geologists of the foremost rank, and, which is of great importance, of great experience in all that pertains to glacial geology. Foremost among them I would mention Mr. Warren Upham, whose able presentation of the case in Professor Wright's "Ice Age in North America" is well known. He contends that an elevation of large areas above the limits of perpetual snow would be adequate to produce glaciers of dimensions competent to perform the work of which we see the evidence, and that such an elevation did actually take place is held to be proved by the submerged valleys formed down the American coast, *e.g.*, at the mouth of the Hudson, and in the

fiords which indent the western shores of Scotland and Scandinavia. I freely admit that a great uplift might, perhaps *must*, produce glaciers, and I am prepared to accept the evidence of some, if not all the submerged valleys and fiords, but while reserving my main arguments against these views to a later stage, I would point out that no evidence whatever has been adduced to connect the erosion of these valleys with the glacial period, which would certainly, as Professor James Geikie points out, be far too short for the accomplishment of so great a work, therefore they must, on any showing, have been pre-glacial as well as glacial, and if pre-glacial then the uplift can hardly be said to be the sole cause of that great change, or glacial *conditions* would have resulted earlier than that which we know as the glacial period.

I now turn to the second category.

Cosmical Causes. 1. Variation in the temperature of space. Authors have suggested that in our progress through interstellar space we may pass through cold regions, and that an exceptionally cold tract might have brought about the conditions we seek to explain. This could only be the effect of the diminution of star-heat, in itself in the most eminent degree improbable, and, furthermore, absolutely incapable of producing the effect, for, if our sky were ablaze with two thousand stars, each of the brightness of Sirius, their combined heat would, according to Sir Robert Ball, amount only to one ten-millionth of that which reaches us from the sun. Professor Newcombe places it at a higher figure, viz :—one-millionth of the Sun's heat, but, even upon this more liberal estimate, it will be seen that the *total* withdrawal of this source of heat would be quite without perceptible effect upon climate. 2. Diminution in the amount of heat radiated from the Sun. This theory was supported by Balfour Stuart, but was declared by Tyndall to be inadequate, for, according to his view, "*more* heat instead of less" was needed for the production of a glacial epoch. "What they needed were *condensers* sufficiently powerful to congeal the vapour generated by the heat of the sun." It is perfectly true that heat to evaporate moisture into the atmosphere within the Tropics is a necessity of the production of snow, and therefore, of glaciers; but Tyndall's logic is seriously at fault, inasmuch as it is based upon an assumption which he makes no attempt to prove, and indeed does not seem to have considered. Croll, Sir Robert Ball, and others, accept Tyndall's *ipse dixit* without examination, yet a very brief inquiry will, I think, show that the theory must not be hastily dismissed, but is as much, and perhaps more entitled to serious consideration than any which has yet been advanced. Suppose we imagine the Sun's heat to be so intense that a freezing temperature was never reached in any part of the earth, then it will be obvious that no

accumulation of snow will be possible, however great the evaporation. With less and less solar heat, more and more snow will be precipitated, until at last a diminished evaporation will come into play, and, conceivably, all snowfall might cease for lack of evaporation. Now between these two conditions, on the one hand no snowfall because of too high a temperature, and on the other no snowfall because of too low a temperature, there must be an intermediate term where evaporation and condensation are so proportioned that snowfall will be at a maximum. What that intermediate point may be Tyndall should have determined before he made the statement quoted, and, failing such a determination, Balfour Stewart was as much justified in assuming that it was a lower temperature than the present, as Tyndall was in declaring it to be a higher. There are other considerations, too, that have been very generally overlooked, and which seem to me of great importance. If we survey the existing conditions of the Arctic regions, we shall see that the glaciation, broadly speaking, diminishes with the latitude, so that in Northern Greenland and Northern Grinnel Land, no glaciers descend to sea level. The reason of this is not far to seek. The polar regions are hemmed in by land masses on every side except where the Greenland Sea runs up from the North Atlantic, consequently the moist winds are wrung of most of their moisture before they get within the Arctic Circle, and have little remaining to precipitate. Now, if the lines of equal temperature were to descend so that the isotherm of 32 degrees Fahrenheit passed through the British Isles, we should have the zone of great snow precipitation brought down to these latitudes, while the dessicated area would descend in corresponding fashion. I do not doubt but that the precipitation would be considerably less than at present, but there would, nevertheless, be an amount sufficient to produce glaciers of large dimensions in our islands.

The question of how far such a theory would satisfy the geological conditions, and how far, if at all, it is consistent with the facts of astronomy I must reserve for the moment, and pass on to consider the theory which, from its beauty and ingenuity no less than from the genius of its principal exponent, so seized upon the minds of geologists and laymen as to be elevated to almost the position of a dogma. 3. The combined effects of an increased eccentricity of the earth's orbit with those of that slow and continually repeating cycle called the Precession of the Equinoxes. Dr. Croll brought this theory into prominence, and according to his contention it would follow that during periods of high eccentricity each hemisphere would, for a period of 10,500 years, be glaciated, while the opposite hemisphere would enjoy a genial climate. Dr. Croll calculated from a formula by Leverrier that

two such maxima occurred 850,000 and 200,000 years ago respectively. The former of these was by far the most extreme, but Dr. Croll considered that it was too remote to be identified with the Post-Pliocene glacial period, the geological evidences of the recency of which have been stated by him in terms so explicit and emphatic that some authors in agreement with him upon the general question have fancied that he had indulged in unconscious exaggeration. Dr. Croll saw that his theory would involve the acknowledgment of groups of glacial periods alternating with mild interglacial periods at irregular intervals throughout geological time, the last group, that which culminated 200,000 years ago, and which he held to have covered the glacial period, being by no means the most severe. This theory practically holds the field in this country, just as the continental uplift holds it in America, and before I proceed to discuss them more at length it will be desirable that I should state briefly the cardinal features of the glacial period which my studies have lead me to recognise.

1. The Glacial Period came on with extreme slowness. From the time when the London Clay was deposited a progressive refrigeration is attested equally by the terrestrial and marine life, and by physical indications. The rich luxuriance of tropical types of vegetation found in our Eocene beds, along with the great volutes and cones, the crocodiles and turtles, show conclusively that our climate must have been much hotter than at present, and the same tale is told by beds of equivalent age on the Continent. In the Oligocene period a slight decline of temperature is indicated which became more marked in the Miocene, and in the British Pliocenes we can in successive deposits trace in the most beautiful manner the replacement of the temperate types of marine life, such as now inhabit the Mediterranean Sea, by hardy migrants from the North; and in our uppermost Pliocenes the change has progressed so far that a practically pure Boreal fauna is found. The flora has not been preserved in a continuous record, but in the so called Cromer "Forest Bed," the most recent of our pre-glacial deposits, a purely Arctic vegetation has been found. So far as I can learn, this refrigeration was absolutely continuous and leads us directly up, without halt, to the extremity of glacial conditions. Physical indications of low temperature first make themselves manifest in the few erratics which have been found in the Coralline Crag. In the Red Crag they are, in the early stages, decidedly rare, but in the upper portion they become fairly abundant, and in the overlying Chillesford beds they are very common. The next stage is represented by the Cromer Forest Bed, and upon that, in direct super-position, come the glacial beds with ice-scratched erratics brought from distant regions.

2. The Glacial Period was of long duration. When we reflect upon the vast amount of work which was accomplished by the ice—one million square miles of the North American Continent is covered with drift deposits to an average depth of 50 feet, and the thickness of detritus can hardly be less in the glaciated parts of England—and the enormous distances to which the ice extended, it can hardly be doubted that an immense period of time must have been required to accomplish so vast a work. I lay no stress upon the thickness of the deposits, for we know that much of the material was thoroughly rotted by prolonged subaerial exposure before the ice distributed it. Prestwich has attempted to estimate the possible minimum duration of the Glacial Period by estimating the distance to which the ice extended from the centres in Canada and Scandinavia respectively, and then calculating the period which would be required for ice to move over such a space, taking as his basis the average rate of discharge of ice from the lobes by which the inland-ice of Greenland drains away. He accepts an average annual discharge of ice down the west coast of Greenland, as a maximum of $\frac{1}{8}$ of a mile on the whole coast (his figures really come out at $\frac{1}{9}$), and a minimum of $\frac{1}{12}$ (again less than the true product, $\frac{1}{18 \cdot 5}$, of his factors). Taking the corrected figures, the rate of ice-flow from the central axis of Greenland would be at a maximum 1 mile in 9 years, and at a minimum of 1 in 13½ years. Prestwich then takes a *radius* of the two great ice-sheets of the Glacial Epoch (the American and the Scandinavian) at 500 miles, and calculates how long it would take any element of the ice-sheet to travel so far. By the corrected figures it would take at the lower estimate 4,500 years, and at the higher 6,750 years. But again Prestwich's method is at fault. We should, in estimating how far the ice had to travel, determine not merely a semidiameter of the ice-sheet, but the maximum distance from its radiant-point or centre of movement. Now the ice-movement in North America on the 89th meridian, W. longitude, extended certainly from the northward side of Lake Nipigon, latitude 51 deg. N. down to 37 deg. N., in Kentucky—12 deg. of latitude or just 800 *miles*; from the radiant-point in Scandinavia the flow extended in some directions to a distance of 1,200 miles or more (Professor James Geikie's maps indicate a flow from Lapland 68 deg. N. to Pavlovsk 50½ deg. N., a distance of not less than 1,200 miles but probably nearer 1,300). Now if we take these two distances and assume that the *net annual surplus over melting* was as great as the present *total ice-flow* in Greenland, we shall find that the growth of the two sheets would have taken :—

	Min.	Max.
American	7,200	10,800
Scandinavian	10,800	16,200.

These estimates are, I am aware, founded upon incomplete data. Thus they assume a similar snowfall throughout, when, in all probability, the snowfalls in both Scandinavia and N. America were, in glacial times, much greater than in Greenland at the present day, perhaps twice as great; but against this may be placed the fact that these old ice-sheets would have to travel over very low and sometimes even negative gradients; and furthermore, the estimate assumes (as Professor Prestwich's did) that the annual surplus of growth over discharge equalled the total flow of ice from the edge of the Greenland ice-sheet, which is a sufficiently liberal allowance, I think, to cover any such neglected factors as increased snowfall, direct condensation upon the surface of the ice, and the like. If this mode of estimation, which I acknowledge is extremely imperfect, be allowed, then it would follow that the mere original growth of the Scandinavian glacier must have occupied not less than 10,800 years, while its period of prevalence and of retreat must doubtless have been considerable.

3. The Glacial Period passed away with great abruptness. The remarkably small number of moraines, such as a slowly retreating glacier would lay down, which are to be seen in England, Wales, and those parts of Scotiand which I have examined, has forced upon my mind the conclusion that the Glacial Period passed away with extraordinary abruptness, and that impression is strengthened by many evidences, physical and biological. The paucity of what are termed "moraines of retrocession" is probably even more marked than it seems, for I have published evidence to show that many moraines which preserve their characteristic form in a striking manner were laid down during a pause in the *advance* of a glacier and not of its *retreat*. Many distinguished geologists, here and in America, seem to favour the theory that at the close of the Glacial Period the ice melted almost as it stood. (See Lamplugh, Goodchild, Winchell, and Upham). Be this as it may, the departure of glacial conditions was a much more sudden affair than the on-coming.

4. The level of the British Isles was much the same at the outset of the Glacial Period as at present. Drift-filled river-valleys, which extend below sea-level, have been found in various parts of the country, and may perhaps indicate a slightly greater elevation of the land at some time anterior to the advent of the ice, though we are unable to estimate how much of the depth is due to the erosive action of the ice itself. Against the doubtful evidence of elevation we have the direct and unimpeachable testimony of the old beach and line of chalk-cliffs near Bridlington, testifying to the practical identity of level then and now. In the South of England the English Channel, a very shallow body of

water, was in existence, as witness the beach at Selsey. The Irish Sea, the Firth of Clyde, the North Sea both south and north of Bridlington, and even such minor features as the Dornoch Frith, the Minch, and Loch Lomond were in existence just before the Glacial Period, as may be seen by the way in which shells were dragged forward out of them on to the land and involved in the glacial deposits.

5. The Glacial Period is a very recent event. Direct measurements have been made of the rate of recession of the Falls of Niagara and those of St. Anthony, and they indicate the lapse of not more than 10,000 years since they commenced cutting their post-glacial gorges, though in the case of Niagara allowance must be made for the fact that the great lakes had another post-glacial outlet. Other methods of estimation have yielded results in striking general accord with these, but in this country no satisfactory method of determination in terms of years has been devised, though many geologists, having regard to the wonderful freshness of the signs of glaciation, the small amount of post-glacial denudation, and the small extent to which hollows among the drift hills have been filled in, have expressed opinions in general accordance with the views prevailing in America. Mr. Goodchild says,* "It seems to me that a period of 20,000 years since the close of that period is amply sufficient to account for all the denudation that can be demonstrated to have been accomplished in post-glacial times." Professor Prestwich† believes that the post-glacial period may come within the limits of 8,000—10,000 years. Croll's emphatic testimony to the freshness of all the glacial features of the country has been already referred to, though it is right to mention that he draws the very inconsistent conclusion that the glacial period is separated from us by an interval of *eighty thousand years!* Estimates have been attempted of the rate of erosion of valleys in the South of England and North of France, but these will be entirely useless until some means are devised of bringing these phenomena into direct relation to the events of the glacial epoch. Inferences from the magnitude of the valleys cut through drift deposits are quite fallacious, as we cannot determine the value to be assigned to the greatly magnified power of stream erosion when huge flood-rushes were coming down during the melting of snow as the ice disappeared. Furthermore, the amount of erosion in a drift country is not to be measured by striking a level from the bluffs on opposite sides of a valley; the streams would always need an original furrow to determine their direction, and in many cases this furrow was even deeper than the present valley.

6. There has been but one Glacial Period. So soon as it

* Ice Work in Edenside, p. 167. † Q. J. G. S., Vol. xliii, p. 407.

became clear that the predominant theory of the cause of the Glacial Period explained, and indeed demanded, a succession of such periods in various, one might almost say in all, geological ages, geologists began to look in earnest for evidence of them, with the result that a number of such periods are considered to have been established. To this conclusion I, in common with many others, demur. The evidence is often of the most shadowy description, *e.g.*, two granite boulders were found in the Chalk in Surrey, an angular slab of coal in the same formation at Dover, and a few other small stones in various other localities; and, upon that extremely slender basis a Cretaceous Glacial Period was postulated, in defiance of the clear conjoint testimony of fauna and flora, and the nature of the formation with its pure Globigerina ooze which we know is strictly limited to temperate seas in these days. The evidence from other formations is sometimes better, sometimes worse, but looked at critically I do not think that in one single case we are driven to invoke a glacial epoch as the most probable explanation. Many of the phenomena are easily accounted for without calling in the aid of ice—for example, the occasional occurrence of rounded boulders *in coal seams*,—while the few cases that seem to warrant our invoking ice-action are far better explained by the occurrence of local glaciers coming down from adjacent high mountains, than by the supposition of a glacial epoch affecting the whole world. It has been well pointed out that most of these alleged evidences of former glacial periods are in proximity to mountain chains either actually existent or cut down in past geological time. The strongest arguments against the occurrence of glacial periods prior to the one great one are to be found in the Arctic regions. The various expeditions have made us acquainted with a great series of rocks from the Silurian down to Lower Tertiary, and not only have we palæontological evidence of the clearest kind that genial conditions prevailed in every geological period represented, but also that throughout the whole period no single glacial episode intervened even far within the Arctic Circle. Baron Nordenskiöld, an observer of approved capacity and unequalled experience, says,* "I have in these strata sought in vain for any sign that, as some geologists have of late endeavoured to render probable, these favourable climatic conditions have been broken off by intervals of ancient glacial periods. The profiles I have had the opportunity to examine during my various Spitzbergen expeditions would certainly, if laid down in a line, occupy an extent of *a thousand English miles*, and if any former glacial period had existed in this region, there ought to have been some trace to be observed of erratic blocks or other formations which

* Geol. Mag., 1876, p. 266.

distinguish glacial action. But this has not been the case. In the strata whose length I have reckoned above I have not found a single fragment of a foreign rock so large as a child's head." This testimony there is no gainsaying, and in a case like the present, where positive evidence of warm climates—of which the nautili and ammonites are probably as reliable as the swamp-cypresses—is so overwhelming, it is allowable to lay stress upon the negative testimony which declares that these were not the mild interglacial intervals between the rigours of glacial periods, as Croll contended. The ingenious special-pleading by which it has been sought to show that the mild Arctic climates—climates as warm as those now met with 20 degrees further south—might have been produced by a concurrence of favourable geographical conditions, could hardly have satisfied even its authors. If, in those early Tertiary times, the Polar regions enjoyed a temperate climate, so also Southern Europe enjoyed a correspondingly warmer climate, and the conclusion seems to me irresistible that the cause was cosmical and not terrestrial. It is inconceivable that, no matter whether marine conditions prevailed as during the Carboniferous Limestone Period, or widespread land surfaces stretched out during the deposition of the Tertiary beds; no matter whether Europe were broken up into islands during the Jurassic period, or was in its northern parts an arid desert as in the Triassic; be it land, or be it sea, that special combination of geographical condition by which alone a high temperature could be maintained in high latitudes should have obstinately persisted without break or variation.

In brief—Croll's theory which *requires* that there should have been many Glacial Periods in the past receives a doubtful support from the alleged glacial phenomena of the rocks of lower latitudes, but is absolutely negatived by the whole of the Geology of the Arctic regions.

I may now point out, as briefly as may be, how the establishment of these propositions would affect the two principal theories, viz:—1, The "Eccentricity" theory of Croll, and 2, The Continental Uplift theory of Dana, Upham, and others.

1. The "Eccentricity" theory fails, as I think, wholly and entirely, to account for the extremely slow approach of the Glacial Period; the steady and apparently continuous decline of the temperature of Europe from the almost tropical heat of the Eocene period to the Arctic rigours of the Glacial Epoch covers a period of such duration as must have included scores, perhaps hundreds, of those alternating "Glacial" and "Inter-Glacial" periods implied by the theory.

It equally fails to account for its long continuance. Hasten the process of the growth of the great ice-sheets as we may, I

cannot believe that the Scandinavian ice-sheet could have extended to a distance of 1,200 miles of *net* advance (by excess of snowfall over melting) at a greater rate than the present total flow of the Greenland ice, and that would mean that its period of growth would cover at a minimum 10,800 years; then we have its periods of oscillation and prevalence, and the time taken in its ultimate melting, all to be added. The total brought into contrast with the 7,000–8,000 which the "Eccentricity" theory would allow for a Glacial phase shows a disproportion sufficiently striking to seriously imperil the theory.

The rapid disappearance of the ice, conflicts with this theory, as does the recency of that event. According to Croll and those who think with him, the Glacial Epoch is covered by a period of high eccentricity extending from 240,000 down to 80,000 years ago. The calculation is made from a formula by Leverrier, but Sir Robert Ball has in his fascinating little book "The Cause of an Ice Age," expressed a doubt as to the possibility of safely carrying our calculation back so far as Croll has done; but whether he intended to imply that Croll's tables are unreliable for the last 30,000 years of the term covered by them, or whether he referred to the *three millions of years* of past time embraced by the estimate, he does not say. As a layman, without a knowledge of the mathematical side of Astronomy, I can only say that I should have thought that the planetary orbits were sufficiently well-known to admit of the determination for 40,000 or 50,000 years without any serious error. If Croll's figures will stand, then his theory will, I feel convinced, be declared by every competent geologist to be hopelessly at variance with the date which must be assigned to the final disappearance of the ice. It is, as I have pointed out, not merely a question of the rate of recession of the Falls of Niagara or of those of St. Anthony, but all the direct geological evidence points in an unmistakable manner to the recency of the Glacial Period, and by no one has that evidence been more emphatically stated than by Dr. Croll himself.

The uniqueness of the Glacial Period which I have endeavoured to establish would equally be fatal to Croll's hypothesis as he himself admitted.

The long duration of those periods of high eccentricity, one of which is supposed to have corresponded with our Ice Age involves the inclusion of several phases during which our hemisphere would have enjoyed an exceptionally mild climate, and an assiduous search has been made for geological evidence of such warm inter-glacial periods. At first no difficulty was experienced in finding sections which seemed to display a sequence of deposits indicative of alterations of severe and genial conditions; indeed at one time the discovery of a bed of sand or gravel

between two layers of boulder-clay was regarded as *ipso facto* proof of an inter-glacial period. After a time more sober judgment led to the rejection of such evidence, and reliance was placed solely upon those cases in which deposits of peat or beds containing marine shells were interposed between the beds of boulder clay. The marine shells are now generally regarded with suspicion, as they have in many cases been shown to be rémaniés, and the peat beds are gradually being removed from the category of inter-glacial deposits. A typical example of the latter is that at Cowden Glen, which has been found by Mr. Clement Reid to contain common weeds of cultivation, and is therefore regarded by him as erroneously ascribed to an age anterior to the recent period.

The other peat beds in Scotland found associated with the glacial deposits upon other grounds are regarded by Mr. Reid, whose competency to speak upon such a question is unquestioned, as insufficent to prove a mild phase, even if their stratigraphical position were admitted.

Mr. Reid has, however, published evidence regarding that much discussed series of beds at Selsey, in Sussex, which he interprets as proof of a warm period between two spells of great severity. I have carefully studied his admirable paper on the subject, and, while accepting without any hesitation his statements of facts, am compelled to regard them as quite indecisive in their bearings upon the question. A bed of mud containing many southern species of Mollusca is undoubtedly overlain by a deposit produced during a cold period, but its relation to a gravel containing large erratics cannot be determined by the ordinary test of superposition, and the evidence of included fragments can be quite as easily interpreted, I think, in favour of the greater age of the mud bed than the erratic bearing gravel, as contrariwise.

The Selsey section is the only one in England that at all approaches the nature of proof of an inter-glacial period—the evidence of the Kelsey Hill gravels having been already challenged by Mr. Lamplugh, and, failing better evidence, I do not think we can safely attempt to support the Eccentricity hypothesis upon grounds so uncertain.

In view of the vast number and variety of the drift sections in Britain, and the number and ability of their investigators, it is perhaps allowable to lay some stress upon the failure of the followers of Croll to produce one clear and unimpeachable piece of evidence upon a point so vital to their theory.

2. The theory of a continental uplift is not open to any of the objections urged against the Eccentricity theory. Neither date nor duration furnish any legitimate grounds for the rejection of

this theory, and there is, unquestionably good evidence of great earth movements in late Tertiary, or in Quarternary times. The great submerged valleys down the Atlantic coast of North America are, I think, perfectly good evidence of a former higher level of that side of the continent. The deep hollow of the great lakes, extending down below sea-level, has been cited as further proof, but I strongly question its validity. I do not dispute that the soundings show the lake basins to be old river channels, but their conversion into a chain of lakes could so easily be brought about by a quite imperceptible local warping of the earth's crust, that I should hesitate to call in any other agency. Other great lakes, notably Lake Baikal, extend so far below sea-level, and are yet so hemmed around by live rock as to render it almost a matter of certainty that differential movement has operated, and to render it in the highest degree unsafe to base any supposition of *continental* depression upon such lake basins.

The shores of Europe bear testimony to considerable earth movement in geologically recent times in the shape of submerged valleys (*fiords*), as do, by the way, those of Africa about the mouth of the Congo; but, as I have already remarked, these are not proofs of elevation in glacial times, but, on the contrary, furnish a well-nigh fatal argument against the uplift theory, for the whole lapse of glacial time would not suffice to cut out the mighty Sogne Fiord, with its 4,000 ft. of depth below sea level, and, if the elevation were pre-glacial it ought to have produced a glacial condition then.

The distribution of the Pleistocene mammalia has been taken to indicate an elevation of the Mediterranean region variously estimated at from 1,000 to 3,000 feet; but not only is it unjustifiable to postulate an uplift of the whole area in order to account for the production of an Isthmus connecting Spain with Morocco and Malta and Crete with the mainland, but the *date* has not been brought into agreement with that of the Glacial Period. The evidence of these uplifts are not found in the occurrence of boreal animals in Africa, but in the range of the African elephant, the hippopotamus, the lion, and other at present southern types into Europe. This seems to indicate that the junction belonged to a much earlier period.

But there is another argument, which is I think even more conclusive, that no such condition could have prevailed during the glacial epoch, viz.:—that when the great migration of Northern animals descended towards Southern Europe, the marine creatures participated in the movement, and many of our familiar Northern Mollusca made their way into almost every part of the Mediterranean from the Egean Sea, to the shores of Sicily, where they have been found in Post-Pliocene deposits at great altitudes

above sea-level. Now it is clear from this that if at any time the Mediterranean was nipped into a series of lakes, as has been supposed, that such conditions did not persist throughout the whole of the Ice Age.

When we turn to our own shores we find evidence, with which I, for one, am satisfied, that portions at least of Great Britain stood at a higher level at some time before the Glacial Period than they do to-day, for we find old river channels now filled with drift extending in places to a hundred or two of feet below sea-level, but, again, no attempt has been made to prove that the higher altitude was not attained *before* the Glacial Period. The evidence that the shallow seas round the British shores, and even some of the lesser indentations of them, were in existence immediately before the Glacial Period manifested its full intensity, is unquestionable, as it is also that our seas were at that time inhabited by an Arctic assemblage of animals; and the buried cliff at Flamborough shows that there, at any rate, the land stood practically at its present level even down to the actual onset of the Scandinavian Glacier upon our coast.

I need hardly point out that these facts, which cannot be controverted, are wholly irreconcilable with the continental uplift theory, for the British Isles were practically at their present level (the 200 or 300 feet admitted by Professor James Geikie being quite inadequate) during all the initial stages, and on even to the climax as I should say, and we must look to some other cause to account for the Ice Age in Britain; but if in Britain, then elsewhere, for it is inconceivable that an independent agency was at work producing a unique event in the geological history of Britain, at the same time that an episode equally without parallel was brought about in many other parts of the world by totally different causes. The explanation which fails in its application to the case of Britain, must, I think, be rejected for other regions, as superfluous.

Having regard to the widespread effects and their simultaneity, it seems to me beyond all doubt that the causes of the Glacial Period must be sought in the region of astronomical physics, and that the solution of the problem will be found to apply also to the cause of the singular uniformity of conditions in the earlier geological periods, and of those mild arctic climates which appear to have persisted from the Silurian period down to the Eocene, and perhaps to the Oligocene or Miocene.

A brief statement of the general bearing of the geological evidence may be of some advantage in any attempt to formulate the conditions of the problem. Setting aside the earlier Palæozoic periods, we may say that, from the Upper Silurian down to the Oligocene Period, mild conditions prevailed in the Arctic regions without interruption, and that in our own latitude during

the same period climatic conditions not less, but probably more genial, prevailed, notably during the Jurassic, Cretaceous, Eocene, and Oligocene Periods. During this vast lapse of time there appears to have been an entire absence of floating ice within the Arctic Circle.

From the Eocene down to the climax of the Glacial Period in Europe the decline of temperature was steady and continuous. The disappearance of the ice was extremely rapid, and there is a great mass of evidence favourable to the supposition that the climate immediately after the Glacial Period was warmer than that of the present day. It would seem then that the succession of terrestrial climates have been somewhat as follows:—1. An equable climate prevailing over the whole earth from Pole to Tropics (and perhaps to Equator) down to the close of the Cretaceous Period; 2. A differentiation into zones corresponding with those at present existent, but warmer in each latitude than at present. This seems to have commenced in either the Cretaceous or the Eocene; 3. A steady and continuous cooling from the Eocene Period down to the extremity of the Glacial Period; 4. A sudden return to a climate somewhat warmer than that at present prevailing, and a resumption of the cooling which may, perhaps, be still in progress.

With Pre-Tertiary climates I have little concern, but their wide uniformity suggests that we are dealing with a state of affairs in which *direct* solar rays played a less important part than at the present day; but to explain the continuous decline of temperature from the Eocene onwards, we are tempted to call to our aid the Nebular hypothesis and to ascribe it to a slow cooling of the sun. Tyndall's objections constitute the sole argument against the *adequacy* of a diminution of solar radiation to produce a glacial period, and, as I have shown that these objections are based upon an assumption of which no justification has been offered, we may still regard this as a possible cause, provided that it is not opposed either to geological facts or to physical possibilities; and, as Professor Wright says, "This theory of a variable sun cannot be positively affirmed to be true, but so long as it cannot be disproved by astronomical considerations, it remains in the field to diminish the confidence with which we support other hypothesis." The doctrine that our earth is a cooling body, and that it was once, in common with the other planets, cast off from the sun, is so fully adopted that none, probably, ventures to dispute it. The same hypothesis is applied to the sun itself, and though physicists have exercised their minds over the problem how the sun maintains its high temperature despite the prodigal expenditure of radiant energy, yet all are agreed that the sun partakes of the general tendency. Now if the sun be, like the earth, a cooling body, it

follows that in the early geological ages it was much hotter than now, and in times less remote its heat was less excessive. If we accept this view without any modification, and believe the radiation of the sun's heat to have been continuous, we should have to regard its terrestrial effects as a tendency to a progressive lowering of temperature from the earliest times until now, a view easily reconciled with the high temperatures of the Eocene Period, and with the warm Polar climates of all past (*i.e.* pre-glacial) time, but in striking discord with the fact that a mild climate prevails now as compared with the rigours of the Glacial Period. This difficulty has been a continual obstacle to speculation upon this as a possible cause of the Glacial Period, but one fundamental error has been made of assuming that the *temperature* of a body is to be measured by the amount of heat which is given off from it by radiation or other means, though our daily experience of the effect of a non-conducting covering of a steam-boiler, nay even of our own clothing, should have made the fallacy manifest. The question seems to be :—Are there causes operating which could cause the rejuvenescence of a senile sun, whether by an actual increase of heat or simply of radiating power? To this question I think all astronomers would return an affirmative answer. In the first place it is universally acknowledged that our sun is a variable star, having a period of about eleven years, but this helps us very little. When, however, we enquire into the means by which the sun's heat is maintained, we find almost unlimited possibilities are opened up by each of the rival theories. The daily output of solar heat is such that unless there were some means of renewing the supply, the sun would in a few thousands of years, have cooled down to the condition of the earth, and there are two explanations (neither of which excludes the other) by which a renewal of heat may be obtained. Helmholtz has shown that in the contraction of the sun as it cooled a vast amount of heat would be liberated: a contraction of the solar diameter by one ten-thousandth part would cover the total output for 2,000 years,—this cause must operate.

Meyer put forward an explanation which points to a true cause, but its adequacy is very doubtful, viz :—the impact of meteorites. It has been calculated that our globe is daily bombarded by 20 millions of these tiny nomads, of the size of the ordinary "shooting stars," and there can be no doubt but that the sun, from its greater mass and bulk, will receive a proportionately greater number. When, however, the small size of these bodies is considered, it becomes evident that they could not have any appreciable effect except in the rare cases when dense clusters of meteorites are intercepted, which will doubtless occur at remote and irregular intervals. It is doubtful whether Helmholtz's

theory would provide for any considerable variation in the rate of radiation, but the case of the meteoric theory is different. These bodies are very irregularly distributed through space, and, as I have already said, must reach the sun in varying numbers; their variation in size will also be very great, still I am far from believing that they can have any considerable influence either upon the total output of solar radiation, or upon its variation.

There are, however, two phenomena, the one of celestial, the other of terrestrial physics, which suggest not merely possibilities but even probabilities of the highest interest. Astronomers from time to time witness the apparition in the sky of "new stars," which in the course of a few hours or days increase in brightness in an extraordinary degree, and after a greater or smaller number of fitful flickerings, gradually fade almost or quite to their former insignificance. The fact that the evolution of heat is of such brief duration is considered to be conclusive against Newton's theory that new stars were produced by the collision of comets, and there remain two theories to contest the field. The similarity of the spectrum of the Nova in Auriga discovered in January, 1892, to that of nebulæ and comets, and the fact that it can be analysed into two components indicating that the source of light consisted of two bodies moving in the line of sight, one away from the earth and the other towards it, has encouraged those who ascribe to so many celestial phenomena a meteoritic origin, to believe that the phenomena were due to the collision with inter-penetration of two swarms of meteorites. The explanation favoured by Dr. Huggins is that two bodies moving in opposite directions passed sufficiently near to each other to produce a violent tidal disturbance which, while it would doubtless cause some actual generation of heat, would be chiefly effective in disturbing any crust or non-conducting envelope, and so increasing the radiating power of the bodies concerned. In either of these hypothesis, it seems to me, we have a cause suggested which might operate in the case of our sun. Whether it has operated or not, is quite another question, and one with which I am fully sensible of my incompetence to deal. Another and very different class of phenomena is that which is manifested in the behaviour during cooling of many substances which come under the observation both of the chemist and of the manufacturer. I allude to that strange property of iron, silver, and some other metals, of undergoing a sudden and often great increase of temperature at a certain stage of cooling from the molten state. In some cases the evolution of heat produces no change of physical state or condition, while in others the cooling substance after consolidation begins to glow and actually to liquify. So far as I can learn the effect of pressure in determining the temperature at which this recalescence takes place has not been

ascertained, and that of course is a prime factor in any enquiry as to the conditions under which recalescence may happen in the enormous, mainly metallic, mass the sun.

It it no part of my object to attempt to formulate a theory to explain how the sun may be awakened from a torpid state, such functions belong to the astronomer and the physicist, but I wish to show that there are in the realm of celestial physics, no less than in the better known fields of terrestrial physics and chemistry, facts which seem to a lay mind to render the rousing of our sun from a dormant condition, a matter not quite out of reach of legitimate speculation.

My main object has been attained, if I have proved as I think I have, that neither Croll's theory nor the theory of continental uplift will account for the Ice Age; further, I have attempted to show that the time-honoured assumption of Tyndall, that the Ice Age was a period of greater rather than of lesser solar radiation, was without logical basis, and that thus a clear field was laid open to speculation which can hardly do harm, and from which conceivably much good may accrue, not only to geology but even to those sciences to whose autocratic decrees geologists have so meekly bowed.

I would remark, in conclusion, that the arguments I have advanced belong as much to Mr. J. W. Gray, F.G.S., as to myself, and that the present communication should be regarded as an amplification of the paper read by us at the Edinburgh meeting of the British Association.

MARCH 16TH, 1893.

Mr. JOHN INGLEBY, the President, in the Chair.

"SOME EXAMPLES OF CHANGE IN ROCK CAUSED BY THE PERMEATION OF UNDERGROUND WATER."

BY Mr. B. HOLGATE, F.G.S.

One cannot do much geological field-work without perceiving that almost every rock-bed has been changed in a more or less degree since it was laid down. In whatever direction we look we find examples of this. Our sandstones were once banks of loose sand. Our shales and slates and even some of our schists were once layers of mud. Our mountain limestones were chalks and contained flints as the Cretaceous chalks do now. Some amygdaloids were, in the first instance, vesicular lavas, and have had the vesicles filled up by matter deposited at a later period; and so we may go on multiplying examples and changes. The following are some of the commoner minerals which will illustrate my meaning.

We meet with silica in the form of quartz crystals lining cavities and cracks produced by faulting, and built up at right angles to the faces of the cavity or crack. We meet with the same crystals entire in the shales of the Mountain Limestone near Buxton, where they are called Buxton diamonds. In another form we find the same substance in banded cherts, and again as flints, agates, and chalcedony.

Carbonate of lime may be met with in a greater variety of forms, and in the same positions, viz: as crystals in cavities and in cracks. When met with at the top of a cavity it is in the form of stalactites, when at the bottom they become stalagmites. On the floors of cavities or caves it often forms itself into mineral layers similar in appearance to banded chert. Under water it is deposited as tufa in porous masses.

Sulphate of lime may be met with as free crystals of selenite in the plastic and almost impervious clay of the Gault; also in the shales of the Coal Measures which contain a good deal of sulphate of lime. It also appears as fibrous gypsum in beds of marl when underlying limestone.

We find fluoride of lime as fluor spar in the massive crystalline form known as "Blue John," in the Mountain Limestone of Derbyshire, and also in cubic crystals. Phosphate of lime is found in the transformed substance of the shells and coprolites of the Cambridge Greensand. Carbonate of iron is similarly found in the transformed shells of the Coal Measures where it is pseudomorphous and in the clays surrounding them. It also contracts about other animal and plant remains which form nuclei for its attraction. Sulphide of iron takes the form sometimes of free cubic crystals of pyrites as in the slates of Wales, sometimes as a botryoidal crystaline mass about a nucleus of organic matter, the crystals radiating from the nucleus. At other times it may be found along with lime forming crystals in cavities. Sulphide of lead, or galena, is often found in limestone cracks. Red oxide of iron is found as the kidney ore of the Workington district. All these substances are produced by the chemical and mechanical action of water under different conditions. Water is the great solvent of everything. Upon analysing sea-water from different parts of the ocean, traces of all the known substances are found. The first appearance of this water is as cloud and vapour. Even as it falls the rain takes from the air carbonic acid, and is charged with this gas when it reaches the surface of the earth. When it arrives on the ground, if on moorland it takes up nitrogenous matter in solution. If it falls upon a bed of clay or slate, it nearly all flows away from the surface. If it falls on sandstone, a quantity of it sinks into the rock and permeates through it. The same thing takes place if it

falls upon volcanic ash or lava. If it falls upon chalk, a very large proportion is absorbed into the rock, which is so porous that by capillary attraction it sustains the water at a considerable height within itself, and if the rain is excessive it forms bournes. It does the same thing, but in a less degree, when it falls upon oolitic or other limestone. Over the Mountain Limestone it works its way into the mass of the rock by cracks and joint planes, widening these and forming caverns by its solvent action. Now, in all these cases the water acts in two ways, first chemically, that is, by exchanging its chemicals time after time as it meets with one ingredient after another; and mechanically, that is, by actually wearing away the rock and transporting it. It acts in different ways upon different rocks. If it falls upon sandstone rock, which is faulted and broken at the surface, so much as to become shattered (and we meet regularly with many such examples in this district), the basic constituents and nitrogenous compounds, the result of decomposition of vegetation, penetrate further and further from the outside of each piece of rock towards its centre, these constituents are exchanged and concentric rings of oxide of iron are formed staining the stone at different depths. If the rocks under these conditions have contained fossils, the water has singled them out for its action, and has left them in a soft, sandy state in the form known to quarrymen under the name of "red horse." It will be found that this "red horse" and concretionary rings generally occur together. When the rain falls upon a fine-grained sandstone, or limestone covered with vegetation, it often penetrates and makes "dendritic" markings. Under ordinary circumstances we do not expect to find any fossils containing structure in sandstones, we only expect to find casts. The sandstones are only a carrying medium for the water. They have been transformed from sand into sandstone, partly by pressure, and partly by the solution of the felspar by water, and the re-arrangement of its molecules. Wherever water has a free and a rapid passage through a stratum of sand, or stone, or gravel, it acts as a solvent. This is the case in the beds of rivers, and in recent deposits of sand and gravel on the hill side. Thus, if we find say a coral in the gravel at a few feet below the bed of a river, it is almost sure to have the lime dissolved out from between the tubes, Flints are acted upon in the same way, but in a less degree, and when broken, are found to be hollow, or changed in the middle. Examples may be found at Newlay, near John o' Gaunt's, and other places. On the other hand, shales, whether in the Mountain Limestone or in the Coal Measures and clays, only allow the water to pass through them very slowly, they become saturated and water-logged, and these are the conditions favourable to the formation of crystalline deposits. As is to be

expected, the substances deposited depend upon the physical condition and chemical institution of the strata through which the water passes. Impervious beds of what have been mud, whether it be the slates, the shales of the Yoredales and the Coal Measures, or the Gault or Tertiary clays, all contain free crystals which may be washed out of them. In the red iron ores, or in the Yoredales or Mountain Limestone, quartz crystals are found; so numerous are they about Buxton that they are known there as Buxton diamonds. In slates are found free crystals of iron pyrites. In the shales of the Coal Measures and in the Lias, Gault and Tertiary clays are found free crystals of selenite, and the same substance in the form of gypsum is found in the Permian marls. In impervious or partially impervious beds which abound in plant and animal remains, we find a tendency to form concretions about the animals and plants, and these concretions are generally of lime, silica, and iron combined but in different proportions. Sometimes they are formed about a single object, at others they embrace a number of them. Sometimes the petrifying medium has only exchanged constituents with the petrified, at others it has formed a nodule about it. To this action we are indebted for our coal balls, which are concretions formed in a seam of coal enclosing the woody or other structure in somewhat rounded nodules. It is clear that this action must have taken place before the woody matter decayed and became coal. Those that are worked are composed mainly of carbonate of lime. Those formed of silica are too hard to be easily sliced for microscopic sections, and those of sulphide of iron soon crumble under atmospheric action and damp. When carbonate of iron predominates the nodules form the nodular clay-ironstone of the Coal Measures. When silica predominates we get flints, the stratum through which the water passes being in the latter case limestone, sometimes the Mountain Limestone, sometimes oolite, and sometimes chalk; all these contain flints formed in position by this concretionary action. The flints have been formed by the concretionary action of silica in solution, and in precisely the same way as coal balls and ironstone nodules. Every variety in the mode of petrification which is represented in the one, is represented in the other, the difference being caused only by the different constituents of the strata through which the water has passed. In some parts of the Chalk we find nodules of sulphide of iron in a crystalline form, the crystals radiating from an organic nucleus, the irregularity of their length forming a botryoidal exterior. A similar action has taken place in the formation of the red botryoidal iron ore of the Workington district, but here, instead of being sulphide it is oxide of iron. In cavities, whether they be vertical cracks formed in faulting, or hollows in the beds,

incomplete crystals are built up against the sides. In a limestone country we should expect to find silica and crystals of sulphide of lead or galena. Lime appears to have the power of causing these crystals to form, and I have sometimes met with minute ones in the shells contained in the ironstone nodules of the Leeds district. These cavities also contain quartz and calcite, carbonate of barium, and sulphate of barium. In faults, the adjoining strata of which consist of limestone and sandstone, I have found crystals of galena and pyrites combined. Under such circumstances the deposits appear to have been made while the cavities and the strata together were filled with water, the cavities having free spaces and allowing the crystals to be built in them. Sometimes when these cavities have been narrow the crystals approaching from each side have met in the centre; such examples are often seen. When crystals of different substances are formed in the same cavity—a not uncommon occurrence—they have evidently been caused by the difference in the chemical contents of the water owing to some geological change. So far we know that the water changes its chemical constituents as it passes through the strata and deposits the substances, held in solution, where we now find them. Molten iron when cast in large lumps, contracting as it does towards the outsides, invariably leaves the cavity in the middle lined with free crystals of iron and also crystals of sulphide of iron. Molten iron in the blast furnace deposits among the slag crystals of titanium. The whole subject is a very interesting one. Much remains to be learnt, and with the many opportunities there are in this neighbourhood of studying such changes in rock, caused by the action of water, I lay the subject before you, in the hope that you will examine them practically for yourselves.

MAY 18TH, 1893.

Mr. JOHN INGLEBY, President, in the Chair.

"THE DISTRIBUTION OF PLANTS AND ANIMALS AS AFFECTED BY THE PAST HISTORY OF THE EARTH."

BY PROFESSOR L. C. MIALL, F.R.S., F.G.S., F.L.S.

(*Abstract*).

The lecturer commenced by stating that the facts of the distribution of plants and animals may be conveniently grouped as Natural History Provinces. Within a province there is, with local variations, a general assemblage of living things common to the whole area. Some may occur with a very restricted range, while others are more widespread. One province includes the whole of Europe, North Africa down to the Tropic of Cancer, and

Asia north of the Himalayas and West of the Indus. When we cross the Himalayan Range we meet with many distinct species, and many of the forms common in the Palæarctic province are seen no longer. India and part of China constitute a distinct natural history province which is not confined to the continental land only, but includes many of the East Indian Islands. This is the Oriental province. North America possesses so many features in common with Europe and Northern Asia, that Professor Huxley's inclusion of the whole in his great province of Arctogea perhaps expresses the degree of relationship better than Wallace's separation of it as the Nearctic province. It is a familiar fact that the great land mass of the globe is situated in the Northern Hemisphere, while the Southern Hemisphere has a preponderance of sea, and the land areas are markedly discontinuous. The main portion of Africa lies south of the Tropic of Cancer, which roughly defines the limits of a distinct zoological province—the Ethiopian—which also includes Madagascar. A strong line of demarcation traverses the Malay Archipelago separating the Oriental region from the Australian province, which is characterised most strikingly by the preponderance of the Marsupial types of Mammalia. South America is, again, distinguished by remarkable differences of fauna and flora from North America, and constitutes a Neotropical province. It is to be noted that the zoological regions are not marked by the existence of any physical or geographical barriers; for example, there is none between North and South America, the Neotropical region embracing the southern part of the North American continent. Again, though there is a well-marked zoological boundary passing through the East Indian Archipelago, there is, so far as has been ascertained, no corresponding physical boundary. These different zones, then, have no physical origin, *i.e.*, do not depend upon the existing distribution of land and water, but have an historical one. It is probable that during the later geological periods—the Tertiary and probably also the Secondary—the great continents occupied much the same position as now, allowing however for the minor changes. It is improbable that Europe and Asia have been entirely submerged so as to lose their identity as continents since at least the later Mesozoic period, and during that time there has been a great and practically undivided land mass in the Northern Hemisphere. What effect would this have upon the distribution of plants and animals? Probably there would result a very severe competition for the means of subsistence, and the consequent origination of large numbers of new species. An illustration may make this clear:—Suppose football clubs to have been established when the means of communication were very imperfect. They would then be confined to particular valleys, and competitions being very local,

one club would soon establish its supremacy, the game consequently not attaining a very high development. Now, the facilities of railway travel have widened the area of competition. This makes the struggle very severe and a high degree of perfection has been attained. The same thing appears to have happened with plants and animals. The wider the unbroken area the more severe the competition, and the more rapid the development. As already mentioned the land masses in the Southern Hemisphere are comparatively small and isolated. South Africa was cut off, down to somewhat recent times, by an inland sea on the site of the great desert. Australia has been isolated for even a longer period, and South America has been often and long separated. In these detached areas competition would be much less severe, and when a temporary bridge was produced by some earth-movement, then migration would flow in from the regions of more severe competition, and forms which had been evolved under conditions of stress would predominate over the inhabitants of the isolated areas. It is a fact of high importance that in the isolated areas many forms of life have survived which have long since died out in the great Arctogeal continent. Almost every family of animals now confined to the southern continents are known to have existed previously in the northern, *e.g.*, the Edentates and the Marsupials. The exceptions are probably due to the imperfection of the geological records. In a volcano the lava-flows extend to varying distances from the centre, and on boring down at the centre all the successive flows might be found superposed. In like manner the waves of life have been propagated to varying distances, and at the centre—the Palæarctic region—all are superposed in the successive geological formations. As a proof of this Professor Miall shewed how the plants and animals which had been transplanted from the Palæarctic province into other regions had overrun them, but that the converse never takes place.

The lecture was followed by a short discussion, in which Messrs. P. F. Kendall, F.G.S., and J. E. Bedford, F.G.S., took part. The proceedings closed with a hearty vote of thanks to the lecturer.

JUNE 15th, 1893.

Mr. JOHN INGLEBY, President, in the Chair.

ANNUAL BUSINESS MEETING.

The Minutes of the last meeting were read and confirmed.

The following were elected Members of the Association:—Mr. Albert Kirk, Mrs. W. L. Carter, Mrs. P. F. Kendall, Mr. E. J. Whitehouse.

Mr. C. D. Hardcastle, an Ex-president of the Association, was unanimously elected an Honorary Member.

The Hon. Secretary, Mr. W. Lower Carter, M.A., F.G.S., read the Report of the Council for the year 1892-93, which was adopted.

The Hon. Secretary, who was acting as Treasurer pro tem., presented the Financial Statement. Owing to the increased cost of the production of the Transactions, and to the falling into arrears of some subscribers, a bill of £20 to the printer had gradually accumulated. A special effort had been made to raise a fund for the clearance of this debt, and a sum of £14 11s. had been raised by private donations. With an increased membership during the next Session it was anticipated that the finances of the Association might readily be put again on a satisfactory footing. The Financial Statement was adopted.

The Hon. Secretary proposed, on behalf of the Council, that, in addition to the ordinary subscribers who are entitled to one copy of the Transactions, the members should be invited to increase their subscriptions voluntarily, the additional amount subscribed to entitle them to additional copies of the Transactions after the following rate :—

7s. 6d.	to	entitle	to 2	copies
10s.	,,	,,	3	,,
15s.	,,	,,	5	,,
20s.	,,	,,	7	,,

It was resolved that the above scheme should be adopted, and that the Members who became increased subscribers might have back numbers of the Transactions, instead of all of the current issue, if they preferred.

The Hon. Secretary proposed, on behalf of the Council, that, in addition to Members and Country Members, a new class of Associates of the Association should be constituted, as follows :—

1. Associates—To consist of Assistant Teachers in the Schools of the City, and such others as the Council may determine. Subscription : 2s. 6d. per annum, to entitle to a programme of the Session and a copy of the current Transactions, with admission to all lectures and excursions, but to no separate notification thereof.

2. Student Associates—To consist of Senior Scholars in the Science Schools of the City, and such others as the Council may determine. Subscription : One shilling per annum, to entitle to a programme of the Session, and to admission to all lectures and excursions, but not to the Transactions, nor to separate notification of the meetings and excursions.

Such Associates and Student Associates to have no right to vote in the General Meeting, the conduct of the business of the Association being retained in the hands of the Members alone.

The election of the Officers for the Session 1893-94 was then proceeded with, and the result was as follows:—

President— Mr. JOHN INGLEBY.

Vice-President— Mr. J. E. BEDFORD, F.G.S.

Treasurer— Mr. CHAS. J. GUMMERSON.

Hon. Secretary—Mr. W. LOWER CARTER, M.A., F.G.S.

Hon. Assistant Secretaries—
Mr. E. HAWKESWORTH,
Mr. S. W. CUTTRISS

Hon. Librarian—Mr. E. HAWKESWORTH.

Members of the Council—
Mr. WM. CHEETHAM, F.G.S.,
Mr. D. FORSYTH, D.Sc., M.A.,
Mr. W. H. GILL,
Mr. T. T. GROOM, B.Sc., F.G.S.,
Mr. JAMES GURNELL,
Mr. B. HOLGATE, F.G.S.,
Mr. J. H. HOWARTH,
Mr. P. F. KENDALL, F.G.S..
Mr. REUBEN NUNNS,
Mr. J. J. WILKINSON.

The Hon. Secretary proposed, on behalf of the Council, that the time of meeting be altered from 8 o'clock to 7.30, that the meetings close at 9.30, and that the Chairman call upon the Reader of the Paper for his reply at 9.20 p.m. This to be the procedure except by special resolution of the meeting.

The question of the suitability of the present rooms for the purposes of the Association was discussed, and a sub-committee consisting of the President, Hon. Secretary, Messrs. Bedford, Forsyth, Kendall, and Howarth was appointed to consider the whole question, and report to the Council, in whose hands the decision was left.

Obituary.

Mr. JAMES W. DAVIS, F.G.S., F.L.S., F.S.A.

At the comparatively early age of forty-seven there passed away suddenly, on the 20th of last July, one of the most hard-working of Yorkshire geologists, by paralysis due to the rupture of a blood-vessel on the brain. Mr. Davis had been suffering from serious indisposition for some months owing to overwork, and had been compelled to go to Grassington and afterwards to Bridlington for entire rest. His friends were hoping that the change would have soon restored him to his normal health and vigour, and the sad news of his sudden decease was a heavy shock to a large circle of friends and fellow-workers. His death is a serious loss to science, and Yorkshire geologists, especially, will miss a leader whose full knowledge was at the constant service of his brother hammer-men, and whose genial and friendly nature made association with him a rare pleasure.

The following notice of Mr. Davis's life and work will have especial interest for the members of the Leeds Geological Association, of which he was an Honorary Member, as it is largely a reproduction of an article written by Mr. Samuel A. Adamson, our late and much-regretted Secretary, for "Research." The portrait which forms the frontispiece to the present part of the Transactions is the one that was attached to that article, and is reproduced here by the kindness of Mr. Frank Tate, of Liverpool.

Amongst that hard-working band of Yorkshire geologists who have done so much to extend geological knowledge and promote research, the late Mr. J. W. Davis held a commanding position. Not only in science did he take high rank, but as a public-spirited citizen, as an active man of business, and as an energetic organiser he also displayed manifold talents. The science of geology was, a few years ago, little understood and appreciated in Yorkshire. Its students were looked upon as visionaries and theorists, and even accounted unorthodox and dangerous; but much was done by Mr. Davis to dispel these misapprehensions and delusions. By his writings he instructed the many, and by his frequent leadership of field excursions he made the science practical, and, at the same time, fascinating, by bringing enquirers and learners into immediate contact with Nature itself.

James W. Davis was descended from an old Gloucestershire family, which had for several generations been actively engaged in the dyeing of fabrics, and also in agriculture. A little over half a century ago the Davis family migrated into Yorkshire, where, in the neighbourhood of Leeds, the subject of this notice was born on April 15th, 1846. As a schoolboy he early began to develop a taste for natural history. Leaving school at fourteen, he at once plunged into active scientific work. At this youthful age he was elected honoray secretary to the Leeds Naturalists' Society. The habits of method thus so early acquired, the aptitude for organisation thus increased, and the earnest and really practical field work thus commenced, were subsequently

proved to be of the highest value. When eighteen, business changes necessitated his removal to Halifax, of which important town he became one of the most popular, hard-working, and prominent citizens, having been thrice elected to the Mayoral chair. Mr. Davis then began to concentrate his attention more especially upon geology, although he also devoted much time to archæological and antiquarian studies. In 1873 his efforts were rewarded by his election to the Fellowship of the Geological Society of London, to the *Quarterly Journal* of which Society he contributed many valuable papers. The Linnæan Society and the Society of Antiquaries shortly afterwards conferred similar honours upon him. In 1876 his attention was drawn to the moribund state of the West Riding (now Yorkshire) Geological and Polytechnic Society, which seemed to be on the point of dissolution. The advent of Mr. Davis to the secretaryship changed this state of affairs, and, by incessant hard work and the application of his business capabilities, he raised it to a prosperous and useful position, extended the sphere of its operations to the whole of Yorkshire, and nearly quadrupled the number of members. At the Jubilee meeting of the Society, held at Ripon in 1887, the opportunity was taken to present Mr. Davis with some mark of the esteem in which he was personally held by the members, and also in some measure to recognise his great services as honorary secretary and editor of the *Annual Proceedings*. Especially useful to Yorkshire geologists is his valuable work on "The Geology of West Yorkshire," written in conjunction with Dr. F. Arnold Lees, F.L.S.

Mr. Davis became a member of the British Association in 1873, and was a permanent member of the General Committee. Those who attended these meetings will remember the good work Mr. Davis accomplished in his careful investigation of the celebrated Raygill fissure in Craven. He acted as Secretary to the Committee on Prehistoric Remains, and as Chairman of the Committee appointed to examine and report upon the Ancient Sea-beach near Bridlington. In connection with the British Association, Mr. Davis's ichthyological researches are perhaps the most valuable. At the Belfast meeting in 1874 Mr. Davis was introduced to those famous palæontologists, the Earl of Enniskillen and Sir Philip Egerton. This led to a careful examination and study of their large collections of fossil fishes, and Mr. Davis's previous knowledge of comparative anatomy, and his predilection for fossil ichthyology led him to make this branch of extinct animal life a special object of research. Amongst his contributions on fossil ichthyology to various scientific societies may be named the monographs published by the Royal Society of Dublin, viz.: "On the Fossil Fishes of the Mountain Limestone of Great Britain" (1883); "On the Fossil Fishes of the Chalk of Mount Lebanon and Syria" (1887); "On the Fossil Fishes of the Tertiary and Cretaceo-Tertiary Formations of New Zealand" (1888). Papers read by him upon this subject before the Geological, Linnæan, and Zoological Societies of London are of acknowledged repute. It will be remembered that Dr. Henry Woodward, F.R.S., of the British Museum, in his inaugural address as President of the Geological Section, at the

Manchester meeting, after briefly reviewing the monographs alluded to above, spoke as follows:—"He is to be congratulated upon having contributed to fossil ichthyology one of the most extensive works published in recent years." Mr. Davis a few years ago, in the company of Mr. Arthur Smith Woodward, visited the most celebrated museums of the Continent to render himself still more conversant with his favourite branch of study.

The exertions of Mr. Davis in connection with that splendid scientific organisation, the Yorkshire Naturalists' Union, must not be overlooked. As President of the Geological Section and as Chairman of the Executive his services were invaluable. He was always ready with his practical experience to conduct arrangements or lead a field excursion; hence his presence and counsel were held in the highest appreciation by his brother scientists. Mr. Davis also took a lively interest in educational matters in Yorkshire, particularly in connection with Mechanics' Institutions, which have done so much to promote education throughout the country for many years. He was an elected governor of the Yorkshire College and a member of its Textile (dyeing and weaving) Committee. He was likewise a governor of Heath Grammar School. He was honorary curator of geology to the Halifax Literary and Philosophical Society for several years, and upon the Jubilee of the society in 1880 was elected to the position of President. During his term of office the museum became a most valuable one for reference and study, and in the report of the British Association upon Provincial Museums it was ranked in the first class. Mr. Davis possesses a splendid geological museum of his own at his seat, Chevinedge, which is acknowledged to contain one of the finest collections in Yorkshire. In addition Mr. Davis was President for some years of the Halifax Geologists' Field Club and Scientific Society. As a member of the Halifax Town Council Mr. Davis rendered signal service to the town. During his period of office he helped greatly towards the adoption of the Public Libraries' Act, and the town now possesses, chiefly through his exertions, an excellent Public Library, with a Fine Art Gallery and Museum attached. He was also a member of the Halifax School Board and Chairman of the Science Committee.

Mr. Davis also laboured hard for the promotion of the study of fine arts in Yorkshire, and his exertions as honorary secretary to the Yorkshire Fine Art Society for four or five years will be long and gratefully remembered. His own collection of water-colour drawings, which he selected to illustrate the history of this art in Great Britain, is well-known amongst the lovers of this particular branch of the fine arts.

The loss of a man of such varied attainments and indefatigable industry will long be felt in his native county, and especially by the societies whose present flourishing condition is so largely due to his untiring energy and business oversight. The attachment of the people amongst whom he dwelt, and whom it was his joy to serve, was strikingly shown by the great concourse that lined the roads leading to the Church of All Saints', Salterhebble, where his body was laid to rest. The funeral procession will long be remembered by those who

were there. In addition to representatives from the various public bodies with which Mr. Davis had been long and usefully connected, representatives of the following scientific societies attended:—Geological Society of London, Yorkshire Geological and Polytechnic Society, Leeds Geological Association, Yorkshire Naturalists' Union, and the Leeds Astronomical Society.

Mr. WILLIAM CHEETHAM, F.G.S.

The regret with which the members of the Association heard of the serious illness and death of our "veteran geologist" was both deep and sincere. One of the founders of the Leeds Geological Association, he was its unvarying supporter and friend, and its welfare occupied no mean place in his thoughts. He was our President during the years 1882-84, and remained officially connected with the Association, as Vice-President and afterwards as a member of the Council, until his death.

Mr. Cheetham was born in Leeds in the year 1819, educated at the Leeds Grammar School, and then apprenticed to the woollen trade at Calverley, with Mr. James Gray. At the age of 19 he commenced business with his brother in a small way, at Clover Greaves Mill, Calverley. In a few years they took the extensive mills at Woodbottom, Horsforth (Clough Mills), and continued there for 40 years. From this business Mr. Cheetham retired about seven years ago.

Though a successful business man, Mr. Cheetham's interest and activity were by no means absorbed in trade. All through his life he was an earnest friend of education, being one of the founders of the Calverley Mechanics' Institute. He worked for the community in which he lived in the promotion of the Calverley and Horsforth District Gas Company, of which he was a director from its formation, and his able management of the same during recent years has done much to ensure the success of that undertaking. No one could come into even casual contact with Mr. Cheetham without feeling the spell of his happy and warm-hearted nature, and this was more especially revealed in intimate social intercourse. For some time he filled the position of Chairman of the Exchange Club, Leeds, a social institution in which his genial nature and fund of anecdote, combined with a pleasant tact, made him a universal favourite. But his "hobby" was geology, and few have done more for the popularization of the rocky science, both by his pen in the weekly papers and by his genial leadership of excursions and enthusiastic descriptions of the local scenery in relation to geology. Mr. Cheetham was an active member of the Council of the Yorkshire Geological and Polytechnic Society, and a Fellow of the Geological Society of London, but his especial interest and work were given to our own Association, and one of his last efforts was a determined attempt to clear off a debt which was seriously hampering our scientific work. Mr. Cheetham's papers were always the results of his own careful observation, and were enlivened by many a passage of wit and lively anecdote. He had a natural love for scenery, and few knew the beauties of English landscape, especially

in out-of-the-way places, as he did. Born at Calverley, and living his long life within sight of its ancient church, the Valley of the Aire, with its picturesque bends, and the twin Valley of the Wharfe, where Nature still holds sway supreme, with the bracing moorlands around, were the scenes of his favourite rambles, and the enthusiasm with which he expounded their beauties was one of the great attractions in an excursion when he was leader.

Among his contributions to local geological knowledge were several papers on the physical characteristics of the scenery in the North of England, chiefly the results of observations during his frequent driving tours. Such were "From the Grits to the Silurians," "A Visit to Shap," "A Geological Tour through Durham into Cumberland." More detailed matters were dealt with in notices of "A Fault at Apperley Bridge," "On a Boulder with cup and ring markings at Horsforth," and "On the Earthquake of April 22nd, 1884, from personal observations in Essex." His strongest point, perhaps, was in vivid description of the geology of scenery from some commanding point of observation, and his addresses on "The Geological Anatomy of Wharfedale," from Almes Cliff Crag, on "Airedale," from "The Hanging Stone," and only shortly before his death on "Wharfedale," from Otley Chevin, will long be remembered by those who were privileged to be his companions. In addition to these he led interesting excursions to Elbolton, Eccleshill, Guiseley, Hawes, Ingleton, and the Winterburn Valley, each being enlivened by his characteristic notes. One of his last expeditions was a driving tour to the Lakes with Mr. Thomas Tate, F.G.S., collecting type specimens of volcanic rocks for the Yorkshire Boulder Committee.

Not only was he familiar with the best English scenery, but he was also thoroughly conversant with the finest parts of the Continent—Norway, the Rhine, the Black Forest, and Switzerland, being tramped again and again, with a keen eye for their typical beauties. But it was with the geological side of scenery that his keenest interest was aroused, and the accuracy of his observation, and the vividness of his memory, were often a surprise to his friends. He was laid to rest, after a long and useful life, in the bosom of the rock he loved so well, surrounded by a large gathering of personal friends and brothers of the hammer, who came to testify to their deep sense of the loss of a genial friend and a comrade true.

REPORTS OF
FIELD EXCURSIONS.

JULY 9TH, 1892.

EXCURSION TO DUNFORD BRIDGE.

YORKSHIRE NATURALISTS' UNION.

Leader, Mr. JOSEPH FIELD.

Only a small party of geologists left Dunford Bridge on Saturday morning, July 9th, and, under a slow drizzle which continued most of the day, adventured an exploration of the moorlands in which the river Don takes its rise. A start was made by the high road to Holmfirth from which, under the guidance of the gamekeeper, we soon diverged, and crossed the valley to reach a quarry on the summit of Snailsden Moss. Here flagstone beds of the Rough Rock series were seen rising at a rather high angle. Continuing along the hillside another quarry was visited where the beds gave indication of a considerable slip having taken place. This section gave rise to some discussion amongst the members. The party then struck up Harden Clough in which a winding moorland stream had cut itself a way down through the black shales overlying the Middle Grits. This little gorge gave many pretty examples of the way in which denudation is effected by a river. At the head of this clough a nice fault was seen bringing up the Middle Grits against the black shales which form the lower portion of the Rough Rock series. Above the grit beds there was three feet of fire clay having thin lenticular bands of hard black ganister at the top. This was overlaid by a little seam of coal, three inches in thickness, and above that came the thick black shales. The opposite slope was now climbed, over sopping moorland, until Cook's Study was reached. This tower commands a wide expanse of country, and the extent of view possible on so grey a day only proved how grand must be the prospect in clear weather. The flagstones here again were seen inclined at a high angle reaching almost to vertical on the eastern side of the quarry, probably due to a fault. The upper edges of the beds were dale-drawn. Several other small quarries, also in the flagstones which lie at the base of the Rough Rock on this hill, were then examined, showing interesting examples of false-bedding and faulting. In two or three cases large masses of shale were regularly dovetailed into the grit beds. After passing through the village of Magden the party visited a large quarry in the Rough Rock. The upper portion was seen to have a band of shale, about two feet in thickness, parting the grits, with one or two inches of coal on the top. A quick walk was then taken to Oxlee, near Hepworth, where the

Halifax Hard Bed Coal and the underlying ganister and fire-clay beds crop out. The getting of coal has lately been abandoned here, and the section was somewhat obscured by slipped earth.

In the absence of Mr. J. W. Davis, F.G.S., the guidance of the party was kindly undertaken by Mr. Joseph Field, of Huddersfield, who gave a report of the day's outing at the General Meeting.

JULY 27TH, 1892.

EXCURSION TO THE MEANWOOD VALLEY.

Leader, Mr. W. L. CARTER, M.A., F.G.S.

The members of the Leeds Geological Association on Wednesday evening, July 27th, met at Hyde Park Corner, under the leadership of Mr. W. L. Carter, M.A., for an inspection of the quarries in the Meanwood Valley. When the party reached the Ridge a short halt was made whilst the leader pointed out the general geological features of the far-stretching landscape. All the country within view was composed of Carboniferous rocks. A fault, which has been traced for a distance of ten miles, starts west of Weetwood, and passes through Meanwood in an easterly direction to Bramham Moor, bringing down the Lower Coal Measures on its southern side to the level of the middle grits of the Millstone Grit series.

The Meanwood Beck, which rises on Adel Moor, after cutting for itself a picturesque gorge in the hard Millstone Grit beds, crosses this fault at Weetwood, and then flows in a wider valley through the softer grits and shales of the Coal Measure series. The ridges on either side of the Meanwood Valley are capped by the Elland flagstones, which lie fairly horizontal. Below this capping lie beds of shale and friable sandstone about 160 feet thick, and at the bottom of the valley the ganister beds proper are found.

The party then descended the Ridge by Batty Wood to visit the quarries of Messrs. B. Rowley and Co. There are two ganister quarries worked in the valley, which are separated by a fault, the effect of which in the uplifting of the southern beds was very clearly seen some years back. The southern quarry, as the one which is at present being worked, was then examined, and an account of the beds was given by the leader. The whole section seen is about 36 feet in depth. Under 18 inches of surface soil there comes a thickness of 7 feet of stiff yellow clay, which encloses lenticular pockets of sand at intervals, and is full of angular and subangular pieces of ganister stone. Occasionally a boulder of coarse grit is found, well rounded and decomposed, probably derived from one of the grits of the Millstone Grit series. No foreign rock, excepting one small piece of chert, has been found in this clay, which has been generally considered as the ground moraine of a glacier which moved into the valley from the direction of Moortown. Under this deposit come the Lower Coal Measures or Ganister beds, which are pretty constant in thickness in the sections exposed from time to time. About 5 feet of yellow or brown shales overlie 2 feet 6 inches of black shale. These beds are unfossiliferous, and are frequently

found contorted in a remarkable manner. The lower black shales are ridged up into folds wherever there is a hollow in the surface of the underlying ganister. Above these sharp ridges the yellow shales are bent in like manner, and often form a series of crumplings, the axes of which run in an easterly and westerly direction, and may be glacial in their origin. Underneath the shales come the ganister beds proper, which are well developed in this district. The uppermost bed is a hard, bluish-white, siliceous rock, false bedded, and containing few stigmaria (the roots of sigillaria). This bed is about three feet in thickness, and overlies ten feet of white and grey ganister, which shows much current-bedding, and is traversed by well preserved stigmaria, with whorls of leaf-like rootlets surrounding the central root, and forming at the point of their attachment the round pits which are so characteristic of these fossils. In this division many stumps of sigillarian trees have been found, with great roots stretching in all directions. Eleven have been unearthed during the last year's quarrying at various levels. The largest one has, fortunately, been well revealed by a shot, instead of destroyed as is usually the case. It stands about the middle of the solid ganister rock, twenty-four feet from the surface. It is four feet in height, and eleven feet in circumference. The trunk is only marked by broad longitudinal flutings; but the large roots, four of which have been exposed to view, have the usual pittings which are characteristic of stigmaria. The largest root was blown off by the shot which revealed the tree, but its course can be traced by the impression it has left on the rock beneath. This cast shows that the first bifurcation took place about 1ft. 9in. from the junction with the trunk on the under-side, but 9in. farther away at the outer edge. This is shown by a very definite cast of the outline of the root, giving a central ridge about 9in. long, with grooves passing off from it to the right and left. The northerly branch appears to have crossed over the next root, and has left an impression on its surface. The other large root, which is well preserved and exposed, bifurcates for the first time about 2ft. from the trunk, on the upper side, and the two branch roots stretch out along the plane of bedding. The second bifurcation of one of them is seen, and takes place 4ft. 6in. from the trunk. Another root is partially exposed on each side. At the bottom of these beds of grey ganister there comes a black bed, which is full of stigmaria, calamites, and other plant remains. Under this comes a seam of coal, about 9in. in thickness, which maintains an even thickness over an undulating surface of underlying fire-clay. This coal seam is frequently traversed by stigmaria which form ribs, as it were, of sandstone, running through the coal. This coal is considered to be the equivalent, in the district, of the Hard Bed Band (48 yards) Coal, which is much more fully developed in the south-west of Yorkshire. Underneath the coal seam come the fire-clay beds, which consist of 1ft. 6in. of hard black ganister, and 3ft. 6in. of softer fire-clay. In these beds two or three trees have been found, and they are traversed in all directions by stigmaria. The whole series is underlaid by a considerable thickness of black shales, which are not worked.

After this quarry had been thoroughly inspected, and specimens obtained, the party took a walk through the pretty village of Meanwood to Mr. Bradley's quarries in Meanwood Wood, where the Third Grits of the Millstone Grit series are worked for building stone. The shades of evening, however, prevented more than a casual examination of these beds, but before the party set off on their return journey hearty votes of thanks were accorded to Mr. Rowley and Mr. Bradley for their kind permission to inspect their interesting quarries.

NOTE:—Since the date of the above excursion excavations have been continued in the ganister quarries belonging to Messrs. B. Rowley and Co., and the foldings mentioned above have been traced further. A fault runs between the two quarries but the folds did not appear to have any relation to it at the time of the above examination. These crumplings were then attributed to the movement of a tongue of glacier-ice from the direction of Moortown, which it was supposed had ground away the outcrop of the ganister beds in that direction and left the surface bed of stony clay when it melted. During the summer of 1893, however, other rapid flexures of the shales were found which were, in this case, clearly attributable to the movement of a small fault along a joint face, and parallel to the main fault which comes a few yards to the southward. No faulting has been yet proved along the line of the fold described in the above excursion, but until further evidence is forthcoming the theory of the glacial origin of the fold and the stony clay must be held in abeyance.—W.L.C.

AUGUST 1ST, 1892.

EXCURSION TO WITHERNSEA.

YORKSHIRE NATURALISTS' UNION.

Leader, Mr. ALFRED HARKER, M.A., F.G.S.

The Great Ice Age has always formed a valuable branch of study to the geologist, as well as a curious and interesting topic to the general mind. Its causes, whether astronomical or geographical, have given rise to much discussion and speculation; its effects have oft-times baffled the ingenuity of those who have tried to elucidate them, and at the present day they still present many important problems for the geologist to unravel.

Generally speaking, it is certain that in comparatively recent times the British Isles were covered by an ice-sheet of great depth, much the same as Greenland is at the present day. By far the greater mass of this ice came from the Scandinavian mountains, coming south-west, filling up the North Sea, and reaching the East Coast of England. Smaller sheets were formed on the Grampians in Scotland, and on the Pennines in the north-west of England. Parts of these masses found their way to the south-east, and eventually came into conjunction with the Norwegian sheet on the shores of the North Sea. As a matter of course, these great masses of ice moving over the country would make terrible havoc of the land surface,

grinding down to a great extent its irregularities, and carrying with them enormous numbers of pieces of rock thus broken off, varying in size from blocks of tons in weight, to the tiniest pebbles. Finally, on the ice melting, all this débris was deposited in the form of terminal and bottom moraines, now known to us as the Boulder Clay. Nowhere in Yorkshire can this formation be better studied than on the Holderness coast, a portion of which was wisely set out for the day's work of the geological section of the Yorkshire Naturalists' Union, on Bank Holiday Monday.

It is to be regretted that so few of our members attended, as those present had a greater treat, geologically, than was anticipated. The fertile country to the east of Leeds looked very beautiful in its morning freshness. The fears caused by a number of black clouds proved to be vain, for after a few drops of rain the weather was almost perfect. On arrival at Withernsea there was a very respectable muster of members and associates, and the different parties were soon on the way to their respective hunting grounds.

The geological party, a large one, as usual, under the very able leadership of Mr. Alfred Harker, M.A., F.G.S., of Cambridge University, took the road over the cliff top, by way of the pretty village of Holmpton, to Out Newton, a point on the coast from four to five miles south of Withernsea. Here a descent of the cliffs was made, rather a rough task, especially for the elder members of the party. The way was then taken on the beach to Dunlington, the highest point in Holderness, and where the cliffs of Boulder Clay attain their greatest elevation. Roughly speaking the cliffs here give the following section:—on the beach, and reaching to about 20 feet above sea-level is the Basement Clay; above this about 20 feet of what may be described as laminated loam; then the whole thickness of the Purple Clay; which is succeeded by the Hessle sands and gravels; the top bed of all being the Hessle Boulder Clay. The Basement Clay is lead-coloured, exceedingly tough, and containing a vast number of boulders, imbedded irregularly, some of large size. Chalk and flint are the most predominant specimens, but an enormous variety is to be found, as may be imagined, considering the varied formations the ice sheet would have to pass over. For instance, the following were observed amongst many others not so easily identifiable:—mica-schists containing garnets; gneissic rocks containing garnets; Silurian limestone with fragments of Trilobites; Mountain Limestone with Productæ, corals, and encrinites; Carboniferous sandstones and coal; Stigmaria; Liassic limestones and shales with Ammonites, Bellemnites, and Gryphæa; Liassic "doggers"; quartz pebbles; and chalk and flint in abundance. Perhaps the most interesting, however, were specimens of two rocks known as Rhomben-porphyr, and Augite-syenite, which are only known to occur *in situ* near Christiania, in Norway. Very remarkable, too, are the chalky, sandy patches, containing marine shells, sometimes perfect but oftener fragmentary. Some of the members were fortunate in obtaining good specimens of these, such as Astarte, Tellina, Saxicava, Dentalium, and Turritella. Our leader explained that these shelly patches were simply boulders, transplanted from the bottom of the

North Sea, and that the shells were not contemporaneous with the formation of the clay. After examining the cliffs at Dimlington as fully as time would permit, the way was taken, on the beach, back towards Withernsea. At one point a very fine section of the laminated loam was seen. This marks a pause in the extreme glacial conditions, and is most probably derived from the Boulder Clay beneath. Some large boulders of Mountain Limestone, Shap Granite, and other rocks were noted on the beach. The Purple Clay is similar in appearance and texture to the Basement Clay, but differs from it in containing a greater proportion of native rocks. It is replaced locally by stratified deposits, which most likely were formed by accumulations of sediment in temporary lakes formed between the moraines and the ice sheet. This clay is perhaps the most extensive of the Yorkshire drift deposits, and in some parts attains a thickness of 60 feet.

One of the most attractive features of the day's work was the examination of sections of lacustrine deposits. It is evident, from the chain of these deposits down the coast, that this part of Holderness was formerly covered by meres, something like the Norfolk Broads of the present day. The only one remaining is Hornsea Mere, and this is fast becoming silted up. These meres gradually became filled up with sediment, and the sea having cut back the cliffs up to them has exposed splendid sections of these deposits. Two very good examples were examined on the way towards Withernsea. One showed a thickness of about 8 feet of marl, containing in parts large numbers of well preserved fresh-water shells, such as Pisidium, Limnæa, and Paludina, also vegetable remains. Some vertebræ of fishes were also found, and one gentleman reported that a day or two previously he had found a complete skeleton of a perch. The marl is covered by a bed of peat, containing grasses, leaves, twigs, and branches of trees.

It can be readily understood that these cliffs of Boulder Clay will suffer severely from the assaults of the sea and the weather. The waste is enormous, and during historic times many villages have been washed away. It has been computed that a strip of land forty miles long, and more than two miles wide, or upwards of 52,000 acres, has been removed since the Christian era commenced. The loss at the present time is estimated at from two to three yards per annum. The clay is carried round by the tide and deposited in the Humber and the Wash.

On arrival at Withernsea tea was served, and the usual meetings held, at which a hearty vote of thanks was accorded all who had helped to make the excursion a success, including our worthy leader.

E.H.

AUGUST 13TH, 1892.

EXCURSION TO DRAUGHTON.

Leader, Mr. W. L. CARTER, M.A., F.G.S.

The wonderful alterations produced in hard, compact rocks by slow earth movements are seldom more beautifully exhibited than is the case in the quarries between Bolton Abbey and Skipton. That the

solid bed of the hard limestone rock, so largely used for road metal, could be bent almost double, without any signs of fracture, seems almost too much to believe; and yet many examples of this rock-folding can be seen and studied in sections which are within easy walking distance of Bolton Abbey Station. Thither the Leeds geologists determined to go on Saturday afternoon, August 13th, but the heavy rain that fell in the morning no doubt damped the courage of many who would otherwise have availed themselves of this opportunity of seeing such excellent examples of contorted beds. Six robust members, however, met at the Leeds Midland Station under brightening skies, and were not disappointed in their anticipations of a fair afternoon. Reaching Bolton Abbey Station, the party set out, under the guidance of Mr. J. Hill, to examine the historical quarry of Draughton. The section exposed in the midst of this picturesque, out-of-the-world village has been photographed and described many times, but the magnificent double fold of thick limestone beds has a fascinating attraction for those who have seen it before, and is a revelation of geological might to those who view it for the first time. The slowness with which the forces acted whose sideways pressure caused these folds, is exemplified in many ways. The solid limestone, in beds four and five feet in thickness, is bent at a sharp angle, in the shape of an inverted V, without the slightest evidence of cracks or dislocation. In some places thin bands of shale are seen between the thicker limestone beds, and where dislocation has taken place the shales are dovetailed into the limestone without the planes of stratification being obliterated.

After a thorough inspection of this remarkable section, the party retraced their steps towards Bolton Abbey, and examined the Hambleton Quarry, which is close to the railway station. The upper part of the section shows a sharp V-shaped fold of shales, with vertical beds of limestone, standing up like great columns side by side. The beds are now being worked below the level of the line, and disclose the splendid folds of which this great uplift is a part. The rocks are found bent into a series of sharp synclinal and anticlinal folds, one of which is so abrupt that it almost becomes bent over into a double fold, and gives the perpendicular character to the beds already mentioned. These contorted limestones form a ridge of low, rounded hills between Bolton Bridge and Skipton, forming the centre of an anticlinal upthrust which throws off the Yoredale and Millstone Grit beds, north and south, to form the moorlands of Embsay and Addingham. This upheaval of limestone forms part of the great anticlinal which stretches from Clitheroe to Knaresborough, and is part of the series of gigantic earth movements which produced the Craven Faults, to which it runs parallel. A good tea proved a refreshing climax to a most instructive excursion, and the party returned to Leeds by the 6.45 train.

AUGUST 20TH, 1892.

EXCURSION TO BRIMHAM ROCKS.

Leader, Mr. CHAS. BROWNRIDGE, F.G.S.

To illustrate various principles connected with physical geology discussed during the winter session, the executive of the Leeds Geological Association wisely determined to visit as many points of interest bearing upon the geological history of our county as possible during the summer months. In furtherance of this object, advantage was taken on Saturday last of an excursion by the North Eastern Railway to Dacre Banks to visit Brimham Rocks. A strong contingent of about twenty four members assembled, and by the courtesy of the North Eastern officials, compartments were reserved for their use, an advantage greatly appreciated by the "old fossils"—and speeding along with passing glances at Carboniferous shales, grits, and Permian limestone, the charming little village of Dacre Banks, nestling in the bottom of Nidderdale, was reached. After long and anxious search for vehicular accommodation for some of the more infirm members of the party, who dare not climb the imposing hill rising in front, and, unfortunately, only partially successful, a start was made to the crags above. The day being a close, hot, and typical "seven-collar day," frequent halts had to be made during the ascent, to allow the "geologesses" to keep up with the party.

Passing over the shell bed above Summerbridge, the country rapidly assumed the characteristic appearance of our grit moors, and here and there, where the road left the harder rock and passed over the softer shales, the deeply cut wheel furrows told at once not only of the geological fact, but of the difficulties of horse and driver on this steep highland road. The Crag grounds being reached, and arrangements suitably made, the party, under the care of the guide, made a general tour of all the principal points of interest; wonderful and weird forms met the party at all turns; rocky resemblance of mushroom, dog, cannon, dancing bear, baboon, sphinx, rabbit, and human form stood outlined at once from the points of vantage selected by the guide at the various halting-places, while the natural arch followed in turn by the wonderful rift or passage of the needle's eye impressed most of the party with wonder, and the latter, by its tortuous windings and narrow passages, with the many interesting—if undignified—climbs over ledges, down furrows, brought home to all the wonderful results of denuding agencies as illustrated by these crags. The idol rock, standing 20ft. in height, and about 40ft. in circumference, stands on a base of softer material, varying from 3ft. to 18in. in diameter, and the numerous logans or rocking-stones all show the result of the powerful, if slow, denuding agencies which have washed away these softer beds, leaving hard gritstone resting and swinging on similar hard and more resisting beds of gritstone below. The various weird and fantastic shapes meeting the eye at all turns, and casting still more eerie and weird shadows from the light of the fine, bright, setting sun, suggested at once the ideal spot for

the dark and mysterious rites of the ancient Druids, who are said to have made this one of their temples.

The rocks composing this district are known as Brimham Grits, forming part of the Middle Grits of the Millstone Grit series, and comprise alternating bands of hard, compact gritstone, and thin and more friable shales; the hard grit resisting the various denuding agencies to a greater degree than the shales, leave great bosses of rock standing on their slender worn bases, to be in time either overturned and cast down the face of the cliff, or form further rocking-stones on the plateau above; the vertical fissures in the rock, further widened out by the effects of the weather, considerably aiding in this process. Here and there on the face of the weather-worn rock the varying hardness could be well noted, and fine examples of current bedding seen in the various faces exposed.

As to the agency to which these wonderful crags owe their shape, there are various opinions. D. Mackintosh, F.G.S., in a paper read before the British Association in 1865, regards it as "an upheaved island, partly spared and partly wrecked by the sea, the passages chiefly excavated by the displacement of blocks, and not so much by disintegration. . . . The undermined appearance presented by this and other rocks at Brimham can only be explained by the laterally-operating agency of the ocean. . . ."

If, however, this ever formed part of an undercut and sea-worn cliff, it is fair to assume that the water would have left similar evidences at other points in the valley; and the explanation would rather appear that glacial action, with its many local influences and variations, has first prepared the ground, to be further wrought into its present fantastic shape by the various sub-aërial agencies of wind, frost, and rain. In the boulders at Norber, near Clapham, and other places, similar results to those at the idol and adjoining rocks—of the weathering away of softer rocks, leaving the harder mass perched on a small pedestal—can be seen; while the powerful if slow agency, in the formation of scenery, of wind, rain, and ice surrounds us at all points.

After a thorough examination of all the points of interest, one portion of the party adjourned to the cottage for tea, the remainder wending their way back to Dacre Banks, where, under the sign of the Royal Oak, a graphic illustration was given mine host of the "denuding power" of a hungry geologist; after which the return train was taken, all being well satisfied with the Brimham illustration of denudation and scenery. C.B.

AUGUST 27TH, 1892.

EXCURSION TO REEVAH.

Leader, Mr. WILLIAM CHEETHAM, F.G.S.

On Saturday, August 27th, a visit was paid by the members of the Leeds Geological Association to the works in connection with the Yeadon Waterworks reservoir at Reevah, near the south-eastern edge

of Rombolds Moor. The party left Leeds by the 1.45 p.m. train for Menston, and then had an uphill walk for two miles to Reevah, where a bird's-eye view is obtained of the works, the sources of the water-supply on the extensive moorlands, and the route by which the water is conveyed to Yeadon.

Reevah is classical ground; a branch of the great Roman road to York passed across the hill, and its commanding position afforded a grand outlook over a vast extent of country. In later years, when the old squire, Timothy Horsfall, occupied Hawkesworth Hall, with shooting and sporting rights for miles around, it was celebrated as the place where the stag was liberated at the annual hunt.

On arriving at the Intake Gate, a short cut over the heather-clad moor brought the party to the works at the conduit, some half-mile above the reservoir, where the large number of boulder-stones furnish sufficient material for the construction of the conduit itself. These and the ground were carefully examined and all found to be sandstones of the Middle Grit, not rounded, and only showing evidence of the watery atmospheric action common at such elevations (832ft.). The Rough Rock, the uppermost of the Millstone Grit series, is *in situ* some two miles to the west on the moor top, and, of course, had once overlaid this district; but its denudation had been complete, and no relics of it were left. Many of the stones were ganister, which, being much harder than ordinary sandstone, were almost as square at the sides as when broken off the bed, and could be used without cutting for the works.

The investigation of the cuttings at the north-west end of the reservoir unfortunately could not be carried out. The clouds appeared to come down and pour their contents upon the party. This would be all right for Yeadon, but was a closure of further observations so far as the geologists were concerned. We may observe that the site has been well chosen, the excavations being made mostly in boulder clay, and no rock *in situ* being met with, the quicksand near the end of the conduit having been the only unlooked-for difficulty. A cursory examination of the southern embankment showed a number of limestone pebbles in the dark boulder clay, and it is to be noted that on the moor the only "travelled stones" were a few specimens of chert found by Mr. Brownridge. The party were much indebted to Mrs. Ainsworth, of what in bygone days was the Gaping Goose Inn, for having thoughtfully and kindly provided a good fire for the drenched members. After tea the return was made to Guiseley Station, which afforded opportunity of seeing Hawkesworth Hall, with its ivy-covered walls, and in front of it the grand course, where the annual steeplechases were held in the old squire's days.—W. C.

SEPTEMBER 15TH, 1892.

EXCURSION TO COXWOLD AND BYLAND.

YORKSHIRE NATURALISTS' UNION.

Leaders, Mr. S. CHADWICK, F.G.S., and Rev. T. A. BURGE.

The hundredth meeting of the Yorkshire Naturalists' Union was well attended by members representing nearly all the departments of natural science. Coxwold was the rendezvous, and the district under investigation extended to the nearest summits of the Hambledon Hills, together with the parks at Newburgh and Gilling, and included Byland Abbey.

The geological party, which included members from Malton, Leeds, York, and Hull, left the early train at Gilling Station, where they were met by the Rev. T. A. Burge, Prior of Ampleforth College, who together with Mr. S. Chadwick, F.G.S., of Malton, undertook the conduct of the party.

As the geologists proceeded across the low ground dividing Gilling from Ampleforth College, it was explained that the Coxwold and Gilling Valley is remarkable for the presence of two large faults, which cut off the Kimeridge Clay floor of the valley from the Hambleton Hills on the north, and the Howardian Hills on the south, and is succinctly described by Mr. Hudleston as "A great valley, the result of erosion acting upon a complicated dislocation." The practical effect of this dislocation being that the Coralline Oolite (Lower Oolite) caps the two ranges of hills, while hundreds of feet below, in the intervening valley occurs the Kimeridge Clay (Upper Oolite). Mr. Burge pointed out, on the lower slopes of the valley, several minor landslips, which he said were of constant occurrence after heavy rains. These slips, which occasioned the local agriculturists much inconvenience, were caused by the beds of drift moving forward on the slippery shales beneath them. In the neighbourhood of Ampleforth College a short detour was made in order to see an excavation in the Kimeridge Clay, which, however, was found to be much obscured. But enough was seen to determine the horizon. At the College the members of the party were hospitably entertained by Mr. Burge, and were also shown the museum and the beautiful little church connected with the Institution.

After this agreeable interlude the more serious work of the day began. Leaving the College, the party soon found themselves on the line of one of the great faults before alluded to, and in another few yards the spring which supplies the College with water was reached. Prior to the sinking of this well, which is a very good one, Mr. Burge said the College authorities had been at much trouble and expense in boring for water in different parts of their grounds, but without success. As a last resource, a local celebrity with his "divining rod" was called in, and he, to the everlasting confusion of scientific scoffers, without hesitation indicated the spot where the present well now is. A stiff climb of ten minutes brought the party to a large quarry of Calcareous Grit, which proved fairly fossiliferous. A fine specimen

of the genus *Astropecten* occurred here, which Mr. Chadwick regarded as the "find" of the day, and *Ammonites plicatilis*, *Rhynchonella thurmanni*, *Gryphæa*, etc., were noted. After a further ascent the brow of the hill was reached, and another quarry inspected. This proved to be a good section of Coralline Oolite, and resting on the top of it three or four feet of Coral Rag. This exposure, says Mr. Hudleston, marks the highest elevation attained by the Coralline beds in Yorkshire, viz., 675 feet above sea-level. A halt was made there, and many good specimens were obtained from its weathered walls. From the top of the hill close by, atmospheric conditions being exceptionally favourable, extensive views were obtained of the region of the Tabular hills, the Vale of Pickering, and also of the Howardian range to the south—the whole forming a panorama of hill and dale not easily forgotten by students of denudation. Near Ampleforth village one or two sections lower down in the series were visited and yielded fine specimens of Oolitic chert. Here the Rev. T. A. Burge, who had proved such a capable and courteous guide, was obliged to leave the members, but not before they had expressed to him their warmest thanks for his services.

E.R.W.

MAY 20TH, 1893.

EXCURSION TO OTLEY CHIVEN.

Leader, Mr. WILLIAM. CHEETHAM, F.G.S.

Under the leadership of Mr. W. Cheetham, a party of ladies and gentlemen made the first field excursion of the season to Otley Chiven, on Saturday afternoon, 20th May. Taking advantage of the fine weather, the party elected to journey to the rendezvous by road, which proved an enjoyable though rough ride, the latter portion of the road approaching the top of the Chiven not being remarkable for its excellent condition. A happy choice was made in the destination, a spot situated on the highest ground at the edge of the hill overlooking Otley; from nowhere else in the immediate neighbourhood can such a commanding view of the surrounding country be obtained. The veteran leader having spread out his geological maps, and being surrounded by an eager and attentive audience, remarked that one of the grand pages of Nature's book was spread before them. It was written in many characters, each a separate study, and all worthy of the most careful attention; but their immediate object was to note its geological aspects. The landscape in its varied beauty was the result of its geological anatomy. They were standing at the edge of an escarpment of the Third Millstone Grits, and the valley below was a valley of denudation. It was once occupied principally by shales and the thin sandstones that lie between the Kinderscout and the Third Grits. Taken generally, the rocks on the north side of the valley might be set down as Kinderscout; whilst on the south side, from Harewood to Addingham Edge, as Third Grits. Looking directly below, the escarpment was formed of screes, that is, material no longer *in situ*. The boulders were the debris of the upper rocks which had fallen when the underlying shales, which once supported them, were denuded

by water. From their present position they did not see much of the shales, but in going from Otley, either by road or rail, towards Menston, fine examples might be seen, which showed the dip of the strata well and explained to the geologist how the valley had been formed. The strata dipped considerably towards the south, as a result of which the soft shales would be exposed to the disintegrating influences of the atmosphere and water. As the shales were removed, the overlying rocks would fall down, and the surface present the rugged and shagged aspect it did to day. The subsidences at Fewston, in the Washburn Valley to the north, were very extensive, showing the widening of valleys in actual progress, the whole village resting on ground broken down from the northern escarpment. As before mentioned, the top of the Chiven is an excellent point from which to obtain an extensive view of the surrounding country, and the various objects to be seen under favourable conditions were noted. On a clear day, with a good glass, the shipping on the Humber can be discerned, Garrowby Hill (Chalk), 36 miles to the east, and York Minster, 26 miles distant; to the north-east the Hambleton Hills, 30 miles, and Knaresborough, 16 miles; Harlow Hill, Harrogate, Almes Cliff Crag, and Norwood Edge crowning the ridge over Lindley Reservoir; Leathley old church, with the stocks at the gate, and Farnley Park spread below. Tradition says the various groups of trees in and around the park were planted soon after the battle of Waterloo, and represent the position of the allied armies there. To the west are the well-known Cow and Calf rocks above Ilkley, while opposite is Beamsley Beacon. Further up the valley may be seen Earl's Seat and Simon's Seat, 1,592 feet above the sea, and the fainter outlined mountain a little to the right is Great Wherneside, 2,245 feet, and 23 miles away. Mr. Cheetham concluded his remarks by observing that in the magnificent panorama there was scarcely a spot that did not recall to him some pleasant recollections of excursions on foot, in the saddle, and in conveyance. The intellectual feast concluded, attention was directed to the grosser craving of our human nature, after which the party returned, feeling that they had spent a very pleasant and withal profitable afternoon. A geological excursion with Mr. Cheetham as leader can always be looked back upon with pleasure.—S. W. C.

MAY 22ND, 1893.

EXCURSION TO AYSGARTH.

YORKSHIRE NATURALISTS' UNION.

Leader, MR. J. G. GOODCHILD, F.G.S.

The principal object of the Geological Section on the occasion of this visit to Aysgarth, was to compare the development of the Lower Carboniferous Rocks of Wensleydale with their equivalent strata in the dales to the north. Without entering into details, for which reference should be made to the maps and memoirs published by the

Geological Survey, the nature of the differences between the types of rock prevailing in each of these areas may be gathered from the following outline of the geology of the district.

Wensleydale proper consists mainly of Lower Carboniferous rocks, which lie almost horizontally over the greater part of the area. What inclination the strata may have over any part of the district is generally very small in amount (neglecting the areas around Carperby Scars); and may be said to be, in a general way, towards the north around Hawes, and towards the north-east in the district around Aysgarth. The fall of the bed of the Yore from Hawes to Aysgarth keeps almost exact pace with the dip of the rocks; so that nearly the same strata form the river-bed all the way from the village of Hardra to a mile or so below Redmire. To the east of that point the rocks dip faster than the fall of the river bed, so that successively higher strata descend to the Yore as it is followed towards the lower end of the dale.

The dale may be said to be carved mainly out of a great pile—some fifteen hundred feet in thickness—of alternations of limestones, sandstones, and shales, together with chert beds and coal seams. All these are of marine origin, and form the Yoredale Rocks of Professor Phillips. This member of the Carboniferous Series can be traced without any important break, from Craven, through the north of England, into the basins of the Clyde and the Forth.

Below the Yoredale Rocks, whose lowest limestone is that of Hardra Fors, comes the Mountain Limestone, which is so well displayed around Ingleborough. In Wensleydale its uppermost beds alone occur, and these are seen only at the bottom of the valleys. Here they consist of thick masses of limestone interstratified with some thin bands of shale, and with, at least, one band of sandstone. This latter is seen north of Hawes, at West Burton below the Fors, and again at Redmire Fors. It is the lowest stratum exposed anywhere in the dale. The shaly bands referred to as occurring in the overlying limestone gave rise, by their unequal rate of weathering, compared with that of the limestone, to some of the more interesting waterfalls of the dale—Gale Fors, all three of the waterfalls at Aysgarth,* Abbey Fors at Askrigg, and West Burton Fors.

Above the Yoredale Rocks at one time occurred the whole of the Millstone Grit and the Coal Measures, amounting in the aggregate to many thousands of feet. At the present day nearly all this vast pile has been carried away by denudation (acting at various periods in the past); so that now only fragments of the lowest members of the Millstone Grit survive, and occur as outliers capping the highest fells of the district. A fine display of these Upper Carboniferous rocks is exposed on the summit of Pennel (or "Pen Hill").

The chief lithological changes traceable amongst the Yoredale Rocks were studied in some detail on the ground. Stated in general terms they may be said to be closely connected with the condition

* It should be noted that the local name of the chief fall is Eska Fors. "Aysgarth" is probably an "improved" form of this older name.—J.G.G.

under which the rocks themselves were formed. All through the Yoredale period (most especially during the formation of the limestones and cherts, less so through that of the coals and shales, and least through that of the sandstones), deep-water conditions prevailed over the area where Wensleydale now stands, while to the north-west of that part rivers, flowing south-eastward, were advancing their deltas towards the open sea. Intermittent subsidences during the growth of the deltas periodically carried their newly-formed slopes of mud and sand north-westward as the sea-bottom sank, and in that way periodically superinduced deep-water conditions over areas that would otherwise have shallowed through the seaward advance of the deltas.

Thus towards the north-west of any given point in the dale delta materials, *i.e.*, sandstones, shales, and coals, tend to come on in greater force; while in the opposite direction, or towards the south-east, where deep-sea conditions predominated, such terrigenous deposits tend to thin away, while the organico-chemical deposits proper to clear water, that is to say, the calcareous and the siliceous strata, tend concurrently to maintain their thickness or even to increase. As a necessary consequence the sandstones lessen in importance as they are followed towards the south-east, passing first into shales, and these, by slow degrees, into shales more and more calcareous until, eventually, they pass into pure limestones.

This will serve to explain the predominance of deep-sea limestones over deposits of terrigenous origin as the Yoredale Rocks are followed from the north-west south-eastward. It would also lead us to expect that, as these rocks tend south-eastward they would gradually pass into one undivided mass of limestone. Such appears to be the case, and, in this state they have often been mistaken for the Mountain Limestone proper.

In the course of the excursion special attention was given to the demonstration of the foregoing principles by reference to facts visible in the field. Amongst other geological phenomena noticed was the origin of secondary silica, of which several excellent examples were met with. A demonstration upon this subject was ably given by Mr. Percy F. Kendall, F.G.S. Another subject discussed in the presence of the facts was the evidence for the former existence of a rock-basin extending up the Yore from the upper falls at Aysgarth. It was pointed out that the river has only within recent times, geologically speaking, cut its way through this rock-barrier at Aysgarth and thus drained the above-lying lake. The subject of the origin of the scars and terraces of limestone was also discussed in the field at some length, and it was shown that their present conformation can only be explained on the view that they are due to glacial erosion. Lastly, the origin of the glacial drifts of Wensleydale formed the subject of an interesting discussion. It was pointed out that all the drifts in this part of Wensleydale are of *local* origin; that none of them are marine; and that the till, and the sand and gravel deposits, as well as the moraine-like deposits on the water-shed between the Yore and the Swale, are all of them merely *different*

forms of sediment left behind by the melting of the stony and muddy ice of the great ice-sheet. J. G. G.

JUNE 15TH, 1893.

EXCURSION TO ASKERN.

YORKSHIRE NATURALISTS' UNION.

Leader, MR. J. W. STATHER, F.G.S.

The geologists first visited the large gravel-pit to the S.W. of the village, where the so-called Estuarine Beds are seen. This series of beds had been altered a good deal by the progress of recent excavations, and consists now of (1) a bed of soft sandstone with lines of marly inclusions, the whole dipping steadily to the eastward. This bed was traversed by several faults which did not, however, affect the overlying beds. (2) A great thickness of coarse gravel with intercalations of sand. The stones in the gravel were exclusively Magnesian Limestone, rounded, sub-angular, or quite sharp, and ranged in size from small pebbles to blocks three feet in diameter. This bed rested upon an eroded, stepped surface of No. 1. No false-bedding was observed in the gravels or in the underlying sandstone. Mr. P. F. Kendall, F.G.S., who accompanied the party, expressed the opinion that the sandstone was probably of Permian age, and that the gravels were produced by the action of streams flowing over the Magnesian Limestone, during the Glacial period, when all porous rocks would be rendered impervious by being permanently frozen at a little distance from the surface. Under such circumstances the summer rains, and more especially the melting of snow in the spring, would give rise to great rushes of water down the valleys, sweeping before them all the fragments of rocks lying loose upon the surface. Along the eastern edge of the Magnesian Limestone, where it falls away beneath the Alluvial deposits of the Don valley, such streams would probably drop their loads somewhat suddenly when they met the large body of relatively still water that seems to have occupied the area during Glacial times. Such an explanation, Mr. Kendall said, had been offered of the origin of the Coombe-rock of Sussex, by Mr. Clement Reid, of H.M. Geological Survey.

The party next proceeded via Sutton, seeing on the way an example of false-bedding in the Upper Magnesian Limestone, to Campsall, where a gravel and sand pit was visited showing features similar to those exhibited at Askern. The gravels differed, however, in containing, besides Magnesian Limestone, pebbles of quartz and of a coarse red sandstone. The sandstone underlying this series was found to contain similar quartz pebbles, and in an adjacent builders' yard the sandstone was hard and identical in appearance with that of the gravels. The party returned to Askern via a limestone quarry to the north of the village, where obscure traces of fossils were found. J. W. S.

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1893 *Hardcastle, C. D., 31, Victoria Place, Camp Road, Leeds.
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1891 *Marr, J. E., M.A., F.R.S., Sec. G.S., St. John's College, Cambridge.
1874 *Miall, Professor L. C., F.R.S., F.G.S., F.L.S., Highfield, Ben Rhydding.
1887 *Sollas, Professor W. J., D.Sc., F.G.S., 4, Clyde Road, Dublin.
1887 *Spencer, Jas., 8, Salisbury Place, Akroydon, Halifax.
1890 *Woodward, A. S., F.G.S., F.Z.S., Natural History Museum, S. Kensington.

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1886 Ackroyd, Wm., Wheatleys, Birkenshaw, near Leeds.
1874 *Allbutt, H. A., M.R.C.S., 24, Park Square, Leeds.
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1882 *Bedford, J. E., F.G.S., Clifton Villas, Cardigan Road (*Vice-President*).
1874 *Bell, Thos. W., 10, Winfield Mount, Blackman Lane, Leeds.
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1883 *Brownridge, Chas., F.G.S., A.M.I.C.E., 26, North Road, Birkenhead.
1889 Burlend, Geo., Newthorpe Lime Quarries, near South Milford.
1887 Carter, Geo. F., Boro. Engineer's Dept., Municipal Buildings, Leeds.
1889 *Carter, Wm. Lower, M.A., F.G.S., Hopton, Mirfield (*Hon. Secretary*).
1893 Carter, Mrs. W. L. do.
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1876 *Gill, W. H., Park Cottage, Stourton, Leeds (*Member of Council*).
1879 Gould, Isaac, Hillidge Road, Hunslet.
1893 Green, Upfield, Tenter Street, Moorfields, London.
1891 Groom, Theo. T., B.A., F.G.S., Yorkshire College, Leeds (*Member of Council*).
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1890 Halstead, Samuel, 22, Sunnybank Street, Leeds.
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1886 Kay, Stanley R., 5, Winstanley Terrace, Headingley.
1891 *Kendall, Percy F., F.G.S., 5, Woodland Terrace, Chapel-Allerton (*Member*
1893 Kendall, Mrs. P. F. do. do. [*of Council*).
1893 Kirk, Albert, Buckingham Villas, Headingley.
1892 Lofthouse, J. H., 42, Mayfield Grove, Harrogate.
1889 Matthews, Fredk. J. Arundel, F.G.S., Holly Ridge House, Headingley.
1887 *Metcalf, W. D., 4, Linden Grove, Dewsbury Road, Leeds.
1889 Mitchell, Fred, 98, Albion Street, Leeds.
1893 Monteith, Alexander, Boar Lane, Leeds.
1889 Moore, Rev. H. H., B.A., St. John's Vicarage, Darwen.
1888 Morant, Alfred, Kendall Terrace, Leeds.
1886 Mylne, J. W., Elmwood Mills, Leeds.
1882 Naylor, Benj., The Hawthorns, Winmoor, Seacroft.
1884 Nettleton, Hugh, Borough Engineer, Weston-Super-Mare.
1886 Nichols, A. E., Borough Engineer's Office, Leeds.
1892 Nicholson, John, Chapeltown, Pudsey.
1885 Nunns, Reuben, 41, Whitehouse Street, Hunslet (*Member of Council*).
1887 Oldroyd, Linley, F.S.I., 5, Oxford Place, Leeds.
1887 Oliver, J., Castlefields, Rastrick.
1892 Pawson, Albert H., Lawns House, Farnley.
1886 Pheasey, J., 176, Woodhouse Lane, Leeds.
1874 *Pocklington, H., F.R.M.S., 41, Virginia Road, Leeds.
1891 Pollard, James, 28, Tonbridge Street, Leeds.
1892 Ralphs, A. T., Elmville, Roundhay Road, Leeds.
1885 *Redmayne, John, Grove House, Headingley.
1893 Riley, Arthur, 23, Midland Place, Hyde Park, Leeds.
1885 Ripon, The Most Hon. The Marquis of, K.G., Studley Royal, near Ripon.
1881 Roebuck, W. D., F.L.S., Sunny Bank Terrace, Leeds.
1887 *Rowley, Walter, M.I.C.E., F.G.S., Alder Hill, Meanwood.
1892 Scott, Robert, 21, New Briggate, Leeds.
1893 Simpson, Sidney F., Vincent Place, Hunslet.
1887 Stephenson, John, Brownberries, Horsforth.
1890 Stephenson, W. E., do. do.
1883 Stockdale, Thomas, Spring Lea, Springfield Mount, Leeds.
1888 Swithenbank, Josh., Elm Tree House, Hunslet Road, Leeds.
1892 Teasdale, Washington, F.R.M.S., 255, Hyde Park Road, Leeds.
1891 Thrippleton, John, Burley View, Leeds.
1891 Tiffany, George John, Sholebroke Avenue, Leeds.
1885 Wade, Adam, Millshaw, near Leeds.
1892 Wainwright, E. W., Brooklyn, Birstall.
1893 Whitehouse, E. J., 89, Clarendon Road, Leeds.
1889 Wilkinson, J. J., Burnside, Skipton (*Member of Council*).
1891 Witts, J. W., Borough Engineer's Office, Leeds.
1885 Wood, George, Waterworks Depôt, Victoria Road, Leeds.
1885 Wood, R. H., 15, Bainbrigge Road, Headingley.

LEEDS GEOLOGICAL ASSOCIATION.

ABSTRACT OF ACCOUNTS. SESSION 1892-93.

RECEIPTS.

		£	s.	d.
To Balance...		0	4	7
,, Subscriptions, 1892-93		19	17	6
,, Do. Arrears		8	0	0
,, Sale of Transactions		1	0	0
,, Special Donations :—				
W. Cheetham, Esq,	£1 1 0			
T. H. Gray, Esq....	1 1 0			
J. H. Howarth, Esq.	1 1 0			
C. Brownridge, Esq.	1 1 0			
J. E. Bedford, Esq.	1 1 0			
Jas. Bedford, Esq.	1 1 0			
J. J. Wilkinson, Esq.	1 1 0			
John Hill. Esq.	1 1 0			
A. H. Pawson, Esq.	1 1 0			
T. Stockdale, Esq.	0 15 0			
W. Rowley, Esq....	0 10 6			
F. W. Branson, Esq.	0 10 6			
John Ingleby, Esq.	0 10 6			
A. Farrar, Esq.	0 10 6			
W. E. Asquith, Esq.	0 10 0			
Dr. Forsyth.	0 10 0			
J. Gurnell, Esq.	0 10 0			
R. H. Wood, Esq.	0 5 0			
L. Holroyd, Esq....	0 5 0			
R. Earle, Esq.	0 5 0			
		14	11	0
		£43	13	1

EXPENDITURE.

	£	s.	d.
By Treasurer's Postages (W. H. Gill, Esq.) 1892	0	2	10
,, Hon. Secretaries, Postages, etc.	6	14	5
,, Printing Photographs of Fossil Tree for Transactions	3	2	6
,, Printing and Stationery	24	12	9
,, Mechanics' Institution—Rent of Rooms	1	2	6
,, Do. Caretaker	0	10	0
,, Subscription—Yorkshire Naturalists' Union	0	12	0
,, Do. Leeds Photographic Soc. (Lantern Sheet) two years	1	0	0
,, Mending Microscope injured at Annual Meeting	0	8	6
,, Loss on Waggonette to Otley Chevin	0	13	0
,, Collector	1	4	10
,, Annals of Geology—Blake	0	7	0
,, Balance in hands of Treasurer	3	2	9
	£43	13	1

Examined and found correct, 21*st Aug.*, 1893,

C. J. GUMMERSON,
W. LOWER CARTER.

Leeds Geological Association.

OBJECT—The object of this Association is to promote the study of Geology by means of field excursions, exhibition of specimens, reading of original papers, and discussions.

MEETINGS—The Meetings are held on the third Thursday evening in each month, at Half-past Seven o'clock, in the Old Chemical Lecture Room, Mechanics' Institution, Cookridge Street, Leeds. Previous to each meeting, from 7 o'clock to 7.30, there will be an exhibition of specimens in the same room.

EXCURSIONS—Excursions are frequently taken to places of geological interest, under the guidance of experienced geologists.

YORKSHIRE NATURALISTS' UNION—The Association being affiliated with the Yorkshire Naturalists' Union, each Member and Associate has the title and privileges of an Associate of the Yorkshire Naturalists' Union, and is regularly notified of their Excursions.

Members may introduce their friends (ladies and gentlemen) at the Meetings and Excursions of the Association.

Membership and Subscription.

ORDINARY MEMBERS—Receive the Transactions of the Association as published, and have special notification of all Meetings and Excursions.

One copy of the Transactions.		5/-	per annum.
Three Copies	ditto	10/-	do
Five Copies	ditto	15/-	do
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Members may select their extra copies from the back parts of the Transactions in stock, instead of having all of the current issue.

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STUDENT ASSOCIATES—Senior Scholars in the Schools of the City are admitted to the Lectures and Excursions of the Association on the payment of One Shilling, per annum.

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The conduct of the Affairs of the Association is vested in the Members.

The Subsciptions are due on July 1st in each year, and should be paid to the Treasurer of the Association.

Members changing their addresses are requested to communicate with the Hon. Secretaries, Mr. W. Lower Carter, Hopton, Mirfield, and Mr. James H. Howarth, Newton Crescent, Leeds, from whom also forms of Nomination for admission to membership can be obtained.